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THE ROYAL AERONAUTICAL SOCIETY

APRIL 1961

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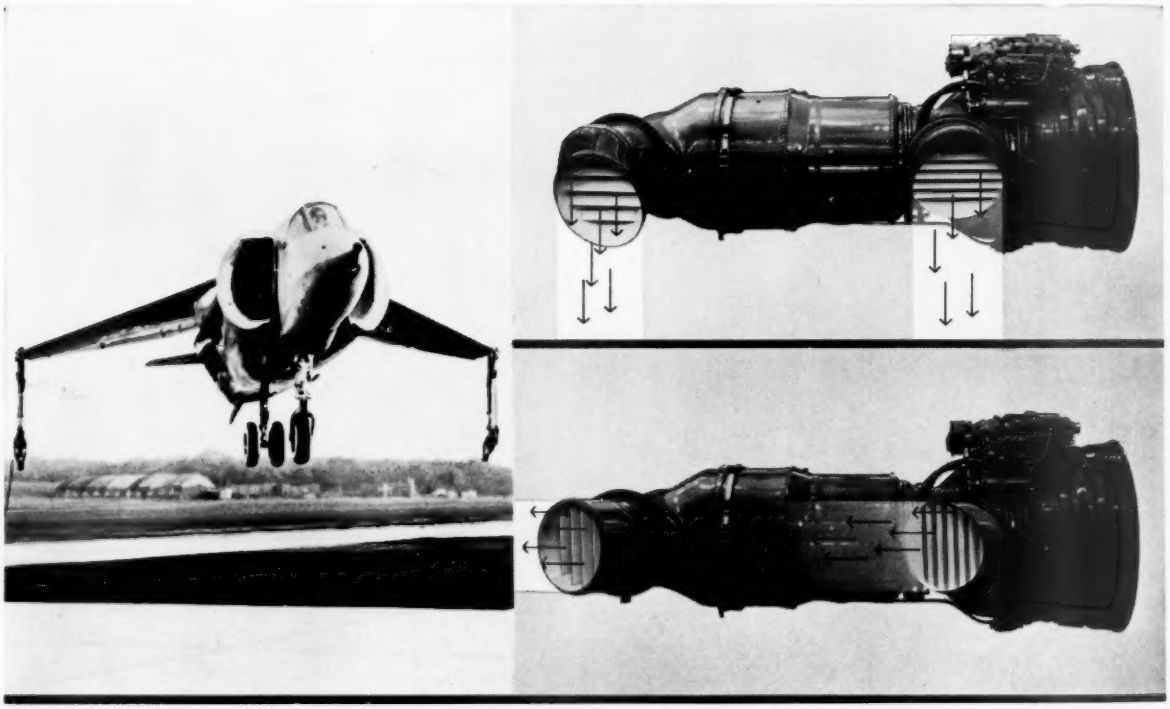

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None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

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NOTICES

Annual General Meeting, 4th May 1961

NOTICE IS HEREBY GIVEN that the Annual General Meeting of the Royal Aeronautical Society, with which are incorporated the Institution of Aeronautical Engineers and the Helicopter Association of Great Britain, will be held on Thursday 4th May 1961, at 6.30 p.m., in the Offices of the Society, 4 Hamilton Place, London, W.1.

Agenda

1. To read the Notice convening the Meeting.
2. To receive and deliberate upon the Report of the Council on the state of the Society and the Balance Sheet and Income and Expenditure Accounts of the Royal Aeronautical Society and Aeronautical Trusts Limited for the year ended 31st December 1960.
3. To receive the names of those elected to Council for the years 1961-1964.
4. To elect the Auditors for the year 1961.
5. Any other business.

By Order of the Council,
A. M. Ballantyne,
Secretary.

NOTE: In accordance with the By-Laws any member whose subscription has not been paid before the first day of April is not entitled to vote.

Light refreshments will be served before the meeting.

Nomination of Candidates for Council

The following is an extract from the amended By-Laws.

(A) *Composition of Council*

The Council shall consist of the President, the three most recently retired Past-Presidents who are willing and able to serve, the President-Elect, the President of each Division, and twenty-one ordinary members of Council. In addition the Chairman of each Section shall be a member of Council by reason of his office, if he is not already a member of Council.

(C) *Ordinary Members of the Council*

The twenty-one ordinary members of the Council shall be nominated and elected from among the members of the Society. At the date of their election at least ten shall be Fellows, and one each at least shall be an Associate Fellow and an Associate. At least one other shall be a Graduate, unless a Graduate is already *ex-officio* member of Council as Chairman of a Graduates' and Students' Section of the Society.

Of the ordinary members of the Council that number necessary to create seven vacancies shall retire at each Annual General Meeting. Subject to the provisions of this By-Law as to regraded members the retiring members shall be those with the longest service since their last election. A retiring member shall be eligible for re-election.

Nominations of candidates for election to the Council must be received by the Secretary not later than **the tenth day of April** in each year and shall include statements in writing by the candidates that they are willing to serve. The nomination form shall be signed by one proposer and two seconders, all of whom shall be Voters.

Nomination forms may be obtained from the Secretary.

Joint Meeting with the Institution of Electrical Engineers—Correction

The lecture "Electronics in Aircraft and Guided Missiles" by the Rt. Hon. Viscount Caldecote to be given on 18th April will be given at **6.30 p.m. at The New Technical College, Boundary Road, Farnborough,** and *NOT in London* as incorrectly stated in the March Notices.

Man Powered Aircraft Group Annual General Meeting

The First Annual General Meeting of the Man Powered Aircraft Group will be held on 5th May at 5 p.m. at 4 Hamilton Place, London W.1.

Symposium on Air Traffic Control

An All-Day Symposium on Air Traffic Control will be held on Thursday 20th April in the Lecture Theatre, 4 Hamilton Place, London, W.1, beginning at 9.45 a.m.

Air Vice-Marshal Sir Laurence Sinclair, Controller of Aviation Ground Services, will take the Chair. Speakers taking part will be: Group Capt. J. B. Veal, Director-General of Navigational Services; Arnold Field, Master of the Guild of Air Traffic Control Officers; A. E. Slocombe, Superintendent of Air Traffic Services, B.E.A.; Air Cdre. J. B. Russell, Director of Operations Maritime, Navigation and Air Traffic Control; E. W. Pike, Manager, Air Traffic Management Division, General Precision Systems Ltd.; J. Anast, Director of The Bureau of Research and Development, Federal Aviation Agency; G. G. Roberts, Technical Director, Cossor Radar and Electronics Ltd.; Capt. V. A. M. Hunt, Director, Control and Navigation Development and Planning, Ministry of Aviation; R. F. Hansford, Decca Radar Ltd.; B. N. Tomlinson, R.A.E., Farnborough, and J. K. B. Illingworth, R.A.E., Bedford.

Admission will be by ticket only—obtainable from the Secretary, Royal Aeronautical Society, 4 Hamilton Place.

Institute of the Aerospace Sciences

Mr. M. J. Lighthill has been awarded Honorary Fellowship of the I.A.S.

Mr. B. S. Shenstone and Mr. Handel Davies have been awarded Fellowship of the I.A.S.

Symposium on Crack Propagation

The Society will hold a Joint Symposium on Crack Propagation with the College of Aeronautics at Cranfield from 25th to 29th September 1961.

Further details will be published later.

International Plastics Exhibition

The 1961 International Plastics Exhibition—Interplas 61—will be held at Olympia from 21st June to 1st July.

Tickets and information may be obtained from Iliffe Exhibitions Ltd., Dorset House, Stamford St., London S.E.1.

Standards Engineers Conference 1961

The seventh annual conference of engineers and others concerned with the application of standards will be held on 9th and 10th May and will be opened by the Rt. Hon. Viscount Hailsham. Sessions will be held at the Connaught Rooms and at British Standards House.

Full details may be obtained from British Standards Institution, British Standards House, 2 Park Street, London W.1.

Corrosion Prevention

A special exhibition on metallic corrosion and its prevention is being held until 6 p.m. on Saturday 22nd April 1961, at The Science Museum, South Kensington, London S.W.7. Admission is free.

Acknowledgments

The Council wishes to thank Air-India International for the gift of six Commemorative Airmail Covers, three flown each way on the Inaugural Flight of the Boeing 707 Bombay-Tokyo.

The Council also wishes to thank Lufthansa for the gift of 10 Commemorative Airmail Covers which include covers flown on the Inaugural Flights of the Boeing 707 over the routes Frankfurt-Tokyo, Frankfurt-New York and Frankfurt-Hong Kong.

DIARY

MAIN SOCIETY

All lectures in London will be held in the Lecture Theatre, 4 Hamilton Place, unless otherwise stated.

19th April
AGRICULTURAL AVIATION GROUP—A Review of Current Developments in Agricultural Aviation. Dr. W. E. Ripper. **7 p.m.**

20th April
ALL-DAY SYMPOSIUM—Air Traffic Control. **9.45 a.m.** *See special notice.*

25th April
On the Origin, Structure and Growth of Vortex Separations. E. C. Maskell. **7 p.m.**

4th May
Annual General Meeting. **6.30 p.m.**

5th May
MAN POWERED AIRCRAFT GROUP—Annual General Meeting. **5 p.m.**

8th May
HISTORICAL GROUP—Discussion Evening. Continuation of Discussion held on 10th April. **7 p.m.**

9th May
Structural Weight Estimations for Novel Configurations. M. E. Burt. **7 p.m.**

ASTRONAUTICS AND GUIDED FLIGHT SECTION

18th May
The Agena Satellite and the Discoverer Programme. R. Smelt. **6 p.m.**

GRADUATES' AND STUDENTS' SECTION

10th May
Aeroflot. G. A. Yarotski. **7.30 p.m.**

ROTORCRAFT SECTION

5th May
The Helicopter—the First of the V.T.O.L. Aircraft. R. Hafner. **6 p.m.**

2nd June
Development of Stabilising Equipment for Helicopters. P. D. MacMahon. **6 p.m.**

BRANCHES

19th April
Christchurch—Annual General Meeting and Film Show. King's Arms Hotel. 7.30 p.m.
Coventry—Annual General Meeting and Film Show. Herbert Art Gallery. 7.30 p.m.
Weybridge—Annual General Meeting. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6 p.m.

20th April
Derby—Hovercraft. C. S. Cockerell. Hucknall. 5.45 p.m.
London Airport—Annual General Meeting and Lecture—Space Travel. A. V. Cleaver. Senior Mess, B.O.A.C. H.Q., London Airport. 6 p.m.

21st April
Hatfield—Annual Dinner. de Havilland Restaurant. 6.15 p.m.

26th April
Hatfield—The Halford Memorial Lecture. Dr. S. G. Hooker. Main Hall, Hatfield Technical College. 6.15 p.m.

8th May
Hatfield—Annual General Meeting. de Havilland Restaurant. 6.15 p.m.

THE CONTROL OF NOISE

A Conference on The Control of Noise will be held at the National Physical Laboratory, Teddington, from 26th to 28th June 1961.

Admission is by personal invitation and anyone interested should write to the Director, National Physical Laboratory, Teddington, Middlesex, for further information.

AUTOMATION—MEN AND MONEY

The First British Conference on the Social and Economic Effects of Automation will be held at Harrogate from 27th to 30th June 1961. The Conference fee will be 11 guineas. Full details and information about hotel accommodation may be obtained from Mrs. J. Hodson, Conference Secretary, The British Institute of Management, 80 Fetter Lane, London E.C.4.

SUPPLEMENT TO THE OXFORD ENGLISH DICTIONARY

The following is the twelfth list of aeronautical terms for the Supplement to the Oxford English Dictionary for which assistance in tracing earlier references is required. If members know of an earlier use than that given for any word in the following list they are asked to write to the Editor, Oxford English Dictionary Supplement, 40 Walton Crescent, Oxford, giving the reference(s), date, author, title, chapter and page. Thanks are expressed to those who have already responded to these appeals.

flick roll	1928	O. Stewart, *Aerobatics*
flight deck (of an aeroplane)	1949	*Aeronautics*, November
flight deck (of an aircraft carrier)	1924	*Scientific American*, October
flight engineer	1939	*Meccano Magazine*, October
flight path	1911	*Chambers's Journal*, I.4.55
flight plan	1940	*Meccano Magazine*, July
float plane	1923	*Glossary of Aeronautical Terms* (B.S.I.)
flyable, adj. (of weather suitable for flying)	1936	J. Grierson, *High Failure*
fly-in, sb. (of air-borne troops, etc.)	1956	W Slim, *Defeat into Victory*
flying hour	1921	*Aeronautics*, 19th May
fly-over (procession of aircraft)	1947	*The Times*, 31st March
forced landing	1917	" Contact," *An Airman's Outings*
force down (an aircraft)	1917	*War Illustrated*, 15th December
force-land, v.	1934	*American Speech IX*
formate, v. (of aircraft)	1933	*Aeroplane*, 19th April
freighter (= freight-carrying aircraft)	1935	*Flight*, 25th May
fuel injection	1932	*Flight*, 26th February

ONE-DAY CONFERENCE ON INTEGRATED DATA PROCESSING IN BRITAIN AND AMERICA

This Conference will be held on Wednesday 24th May 1961 in the Assembly Hall, Church House, Great Smith Street, London S.W.1, from 9.30 a.m. to 5 p.m. (This is a repeat of the Conference held on 16th February.) Tickets are £6 6s. 0d. each, including light refreshments morning and afternoon, luncheon and a copy of the E.P.A. Mission Report. Full details and application forms for tickets may be obtained from the British Productivity Council (I.D.P. Conference), Vintry House, Queen Street Place, London E.C.4.

ASSOCIATE FELLOWSHIP EXAMINATION

The following candidates were successful in the Associate Fellowship Examination held in December 1960.

Part I—United Kingdom

C. B. Adcock, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

C. P. J. Burden, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

P. D. Cofie-Agyeman, Thermodynamics, Theory of Machines.

I. Fazakerley, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

M. A. Gaynor, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

J. Harrall, Mechanics, Aerodynamics, Strength of Aircraft Materials and Theory of Structures; A. J. F. Hunt, Aerodynamics.

T. S. Keats, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

D. S. Lanigan, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

I. H. Nelson, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

B. Priest, Aerodynamics, Strength of Aircraft Materials and Theory of Structures.

D. J. Sawyer, Aerodynamics, Strength of Aircraft Materials and Theory of Structures; P. G. Sturt, Aerodynamics, Strength of Aircraft Materials and Theory of Structures; G. J. R. Sutton, Strength of Aircraft Materials and Theory of Structures.

M. Tin Tun, Thermodynamics, Theory of Machines.

Part II—United Kingdom

P. Berryman, Theory of Structures C; P. G. Boid, Economics and Management, Production, Aircraft Manufacture.

R. L. A. Cardozo, Theory of Structures A, Theory of Structures B; E. O. Cocksworth, Theory of Structures A, Theory of Structures B, Aircraft Design and Development B; T. Coxall, Theory of Structures A, Theory of Structures B, Theory of Structures C.

I. J. Ford, Theory of Structures A.

G. Hemsley, Theory of Structures C; I. B. Hudspith, Theory of Structures C.

Z. Mahmood, Thermodynamics and Theory of Machines, Piston and Turbine Engines; W. J. Magee, Theory of Structures A, Theory of Structures B, Theory of Structures C; D. G. MacWilkinson, Aerodynamics A, Aerodynamics B, Aerodynamics C; M. C. McGovern, Air Transport, Radio Engineering, Operational Air Transport; R. V. Myers, Theory of Structures A, Theory of Structures B.

C. S. Pollard, Theory of Structures A, Theory of Structures B, Aircraft Design and Development A.

J. A. Ramsden, Theory of Structures A, Theory of Structures B, Aircraft Design and Development A, Aircraft Design and Development B.

Part I—Abroad

H. M. Alexander (Ghana), Pure Mathematics, Mechanics, Physics, Aerodynamics, Thermodynamics.

P. M. Goyal (Poona), Thermodynamics.

A. R. A. Rao (Bangalore), Strength of Aircraft Materials and Theory of Structures.

M. P. Sethi (Delhi), Pure Mathematics, Thermodynamics, Theory of Machines.

Part II—Abroad

A. S. Dhillon (Kanpur), General Design Piston and Turbine Engines.

M. Madhavan (Madras), Theory of Structures A, Theory of Structures B.

B. K. G. Rao (Bangalore), General Design Piston and Turbine Engines, Piston and Turbine Engines.

R. Sampath (Madras), Production; V. Srinivasa (Bangalore), Thermodynamics and Theory of Machines, General Design Piston and Turbine Engines, Piston and Turbine Engines.

Changes of Address or Appointment

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address. He would also like to know of any change of appointment.

When notifying changes please give the following particulars:—

Name (in block letters) Grade of Membership
New Address (in block letters) Old Address

New appointment.—Please give name and address of employer and position held, and former appointment.

Changes of address must be received *before the 15th of the month* in order to be effective for the following month's JOURNAL.

Elections

The following is a list of elections and transfers of membership of the Society:—

Associate Fellows

Charles John Beanland
George Beech (*from Associate*)
Stephen Lawrence Bragg
Richard Cecil Clarke (*from Associate*)
Arthur George Henry Damerell
Philip Morgan Davey (*from Graduate*)
Trevor Storr Davies (*from Graduate*)
Frederick William Ellis
Keith Ewing (*from Graduate*)
Vincent Trevor Forster
Frank French
John Cecil Geering (*from Graduate*)
Leonard Stephen Gore (*from Graduate*)
Donald Reginald Henbest (*from Graduate*)
Donald Henry Howle (*from Graduate*)
John Arthur Knivett (*from Graduate*)
Norman Frank Laurence (*from Associate*)
John Eric Lightfoot (*from Graduate*)
John Geoffrey Lodge (*from Graduate*)
John Richard Maher
Thomas John Methven (*from Graduate*)
Maureen Elizabeth Michael (*from Graduate*)
Frederick Cyril Moss
Theodor Pinkus Selig Opatowski (*from Graduate*)
Geoffrey Raymond Ottey
Peter Ross Philpot
Charles Henry Press
Harsimran Singh
Frederick Henry Turner
Frank Webber (*from Student*)
Cecil Frederick Whitehouse

Associates

Douglas William Butler
Leonard Henry Harriden
Roy Francis Holdnall
Kenneth William Charles Lavanchy (*ex-Student*)
Nesta Magness
Benjamin John Frederick Muller (*ex-Companion*)
Frank Ogden
Leslie John Walters

Graduates

Ronald Frank Barton (*from Student*)
Allan Baillie Blackley (*from Student*)
Samuel Rayworth Dauncey
Gerald Michael Davey (*from Student*)
Alexander David Finlay (*from Student*)
Varadarajan Govindan
John Frederick Hahn (*from Student*)
Thomas Nigel Hall
John Harris (*from Student*)
Derek Charles Hayward (*from Student*)
John Heaton (*from Student*)
Ronald Bernard Hern (*from Student*)
Laurence William Jones (*from Student*)
Patricia Mary Jones
David Lawson Irwin Kirkpatrick
Farrokh Ardeshir Kohiyar (*from Student*)
Raymond Leonard Langton (*from Student*)
Derek Edmund McBrinn
John Francis Skane Martin (*from Student*)
Maurice Millard (*from Student*)
David John Peake
Nicholas John Rowe
Vipinchandra Laxmichand Shah
Henry Brian Spencer
William Reid Thomson
John Walter Lester Warren (*from Student*)
Richard Watson (*from Student*)
Michael Raymond Webber (*from Student*)
Anthony Allen West

Students

Richard Gillingham Abbott
Christopher John Blundell
David Edward Bradley
David Thomas Bradley
Michael Joseph Dannatt
Ian Truscott Darwood
Alan John Dowsett
Thomas Peter Dukes
Charles Barry Ellis
Mosleh Elyamani Elmuthanna
Brynley James Evans
Malcolm Graham Gale
David James Goldsmith
James Hall
Derek Basil Hawkins
John Edward Hesselgreaves
Geoffrey Leonard Horne
Kenneth Peter Lacassagne Langlois
Michael John Lucas
Hans Ludewig
David Swayne MacLaughlin
Victor Mason
Colin Arthur Murfin
Albert Walter Ogle
John Martyn Lewis Reeves
Richard William Sanderson
Michael Sorensen
Christopher John Tibballs
David John Walker
Roger Webster
Ronald Frederick Wenz

Companions

Michael A'exander Hamilton Bellhouse
Eric Clothier
Frank Victor Sharpe

News of Members

Sqn. Ldr. E. L. Baines (*Associate*) formerly R.A.F. Northwood, is now O.C. Ground Engineering Squadron, R.A.F. Waddington.

A. J. Bates (*Graduate*) formerly Design Section Leader, Girling Ltd., Birmingham, is now a Field Engineer, Massey Ferguson (United Kingdom) Ltd.

G. T. Beauchamp (*Associate*) formerly Design Engineer, New Design, R. & D., Lockheed Missiles and Space Division, Sunnyvale, is now Design Specialist, Advanced Planning.

D. P. Bottrill (*Associate Fellow*) formerly with Sir W. G. Armstrong Whitworth Aircraft Ltd., is now in the Aerodynamics Department, Motor Industry Research Association, Lindley.

T. D. R. Carroll (*Associate Fellow*) formerly Assistant Design Manager (Britannia), Bristol Aircraft Ltd., is now Deputy Chief Designer, British Executive and General Aviation Ltd.

C. L. Cowdrey (*Fellow*) formerly Manager of D. Napier and Son Ltd., Luton, has been appointed General Manager.

Wing Officer J. Crampton (*Associate Fellow*) formerly at H.Q., R.A.F. Germany, is now at H.Q. Fighter Command, Stanmore.

A. T. J. Crew (*Associate*) formerly Operations Officer, Tasman Empire Airways Ltd., is now Technical Representative, Aviation Division, Electronic Navigation Ltd., Auckland.

Flying Officer J. D. Davis (*Graduate*) formerly R.A.F. Henlow, is now with the Technical Branch, R.A.F. Ternhill.

Sqn. Ldr. J. W. Diaper (*Associate Fellow*) formerly R.A.F. Lindholme, is now Senior Technical Officer, No. 15 Maintenance Unit, R.A.F. Wroughton.

W. G. Dorkings (*Associate Fellow*) has been appointed to the Board of Nicholas Products Ltd.

H. J. Evans (*Associate Fellow*) formerly Chief Designer, Power Auxiliaries Division, Plessey Company, Swindon, is now Technical Manager (Couplings and Fittings), Hose Division, BTR Industries Ltd.

Sqn. Ldr. M. A. Gee (*Associate Fellow*) formerly Officer Commanding, Air Engineering Squadron, R.A.F. Upwood, has been appointed acting Squadron Leader in D.(R.N.) A.H., Ministry of Aviation.

T. A. Ginsburg (*Graduate*) formerly with Stanley Aviation Corporation, is now Senior Engineer, Advanced Programmes Division, Martin Company, Denver.

Flt. Lt. F. H. Gray (*Associate Fellow*) has been posted from H.Q., R.A.F. Germany to the Ministry of Aviation as an Aircraft Supply Liaison Officer, with the acting rank of Squadron Leader.

J. Hanson (*Fellow*) formerly Deputy Head of Structures Department, R.A.E., Farnborough, is now Chief Superintendent, R.A.E., Bedford.

E. H. Holder (*Associate Fellow*), Principal Production Officer, D.A.W.P., London, has been transferred to R.P.E., Westcott, in charge of Engineering.

A. K. Hunter (*Associate Fellow*) having retired from the R.A.F., is now Service Liaison Officer, A. V. Roe and Co. Ltd., Harrow.

Sqn. Ldr. W. E. B. Hurst (*Associate Fellow*) formerly at the Central Servicing Development Establishment, R.A.F., is now Technical A.A.G.W. at H.Q., Fighter Command, R.A.F.

L. R. Jenkinson (*Graduate*) formerly in the Design Office, Blackburn Aircraft Ltd., is now in the Project Office, Hunting Aircraft Ltd.

F. W. Kennedy (*Associate Fellow*) formerly Assistant Resident Technical Officer (M.O.A.) at Handley Page Ltd., is now Resident Technical Officer (M.O.A.) at Westland Aircraft Ltd. (Fairey Aviation Division) Hayes.

R. M. King (*Graduate*) formerly with Short Bros. and Harland Ltd., Belfast, is now an aircraft stressman, W. Perry and Partners Ltd.

M. Langley (*Fellow*) Managing Director, Tiltman Langley Ltd., has been appointed Technical Director, Beagle-Auster Aircraft Ltd.

A. S. C. Lumsden (*Associate*) formerly an Assistant Secretary of the Royal Aeronautical Society, has been appointed Aviation Secretary of the Royal Aero Club.

J. D. McNaughton (*Associate Fellow*) formerly Chief Design Engineer, Garrett Manufacturing Ltd., Toronto, has been appointed Engineering Manager.

G. Odgers (*Associate*) formerly with Decca Radar, is now a Designer, HML Engineering, Isleworth.

J. A. Radcliffe (*Graduate*) formerly at the College of Aeronautics, is now in the Research Dept., Handley Page.

B. Radley (*Associate*) formerly Test Pilot with Hunting Aircraft Ltd., has been appointed Assistant to the Technical Director, I.A.T.A., Montreal.

A. Rickards (*Associate Fellow*) formerly Inspector-in-Charge A.I.D., Westland Aircraft Ltd., Saunders-Roe Division, East Cowes, is now Inspector-in-Charge A.I.D., Folland Aircraft Ltd., Hamble.

J. Sacharin (*Associate Fellow*) formerly Aerodynamicist, Scottish Aviation Ltd., is now Lecturing in Mathematics at Coatbridge Technical College, Glasgow.

J. E. Sellars (*Graduate*) formerly Aerodynamicist, English Electric Co., Luton Airport, is now on the Lecturing Staff, Department of Mathematics, Royal Technical College, Salford.

L. E. Smith (*Associate*) formerly A.T.C.O., Manchester Airport, is now Air Controller, R.A.E. Trials, Larkhill.

F. R. J. Spearman (*Associate Fellow*) formerly in charge of the Guided Weapons Control Section at Ministry of Aviation H.Q., has joined the Overseas Liaison Group, Department of Scientific and Industrial Research.

F. W. Travis (*Graduate*) formerly a Research Technician, A. V. Roe and Co. Ltd., Manchester, is now a Demonstrator, Department of Mechanical Engineering, Faculty of Technology, Manchester University.

G. A. V. Tyson (*Fellow*) formerly with Dunlop Co. Ltd., Coventry, has been appointed Technical Sales Manager, Dunlop Aviation Division.

I. N. Way (*Associate Fellow*) formerly with the Boeing Airplane Company, Seattle, is now a Design Engineer in the Missile and Space Vehicle Department, General Electric, Philadelphia. (Correction from February Notices.)

Sqn. Ldr. C. Wing (*Associate*) formerly with the Armament Squadron, R.A.F. Wildenrath, is now Works Study I at H.Q. R.A.F. Germany.

J. Wright (*Fellow*) formerly Director, Dunlop Rubber Co. Ltd., been appointed Director Aviation Division.

Professor A. D. Young (*Fellow*) Professor of Aeronautical Engineering at Queen Mary College, has been appointed consultant in aerodynamics to the Beagle Group.

Lecture Summary

STRUCTURAL WEIGHT ESTIMATIONS FOR NOVEL CONFIGURATIONS

M. E. BURT

To be given on 9th May 1961

The aims of structure weight estimation are discussed and a review is given of its development in this country during the past fifty years from the simplest formulae to detailed methods.

The limitations of formulae derived only from statistical analysis of actual aircraft structures are noted. For aircraft of novel configuration it is essential for the weight of the basic load-carrying structure to be estimated by methods which are based upon the actual design and stressing procedures. The principles of "optimum" or "minimum-weight" structural design are a valuable feature of such methods and are briefly described. Statistical analysis, however, is still important for estimating the substantial weight of the joints, cut-outs, transparencies and other features which transform a theoretical optimum structure into a complete and practical one.

The problems of several aeroplane and missile configurations of current interest are discussed, and also the extent to which detailed design work is necessary to provide reliable structure weight estimates for such projects.

The Journal of the Royal Aeronautical Society

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VOLUME 65 APRIL 1961 NUMBER 604

H. B. IRVING, O.B.E., B.Sc., *Fellow.*

HENRY BRAID IRVING, a distinguished aerodynamicist, died in hospital, some months after being seriously injured in a car accident, at Stoke Mandeville, Bucks., on 12th January 1961 at the age of 71. He was born on 25th April 1889, at Hoole, near Chester, one of a large family.

He was educated at the King's School, Chester, and at the Manchester College of Technology, where he was the leading student in his subject and obtained a Bachelor of Science degree with first class honours from Manchester University. After four and a half years of practical and design experience in marine and general engineering on the Clyde he left to undertake aerodynamic research at the National Physical Laboratory early in 1914.

His great contribution towards the advancement of aeronautical science is indicated in some measure by the publication during the twenty-five years at the Laboratory of more than sixty papers. His experimental work in the wind tunnels related in the main to aeroplane stability and control problems and to aeroplane spinning. His best known work concerned lateral control and the use of slotted wings. The papers cover, however, a wide field which includes airships, seaplanes, kite balloons, radiators, stress calculations, and buffeting. He was the first to suggest the use of the slot for the improvement of lateral control, in August 1922, and he published subsequently several papers on this aspect. This was later recognised by the award of the Charles Wakefield Gold Medal by the Royal Aeronautical Society in 1929.

A method of balancing split flaps to reduce operating loads, published in *The Aeroplane* in May 1936, is known by his name and drawings by J. H. Clark in that journal showed the eminent practicability of the idea. A year later he wrote another article for the same journal about a suggested means of obtaining variable wing area. The scheme was to arrange a biplane wing structure so that it might be folded together into a monoplane wing to reduce wing area. It was backed by wind tunnel results obtained from suitably devised aerofoil sections. In this article he wrote "The only alternative (to variable wing area) that one can see is the successful development of boundary layer control either in increasing maximum lift or (a more remote possibility) in reducing drag by keeping the boundary layer laminar."

Much of the early work on ailerons, published like most of Irving's papers in the Reports and Memoranda series of the Aeronautical Research Council, was summarised in articles published in *Engineering* and in a paper in the October 1921, *Journal of The Royal Aeronautical Society*, entitled "The design of aeroplane control surfaces, with special reference to balancing." These dealt with the effectiveness of the controls for a range of angular movements, the hinge moments needed to operate the controls and three methods of aerodynamic balancing using horns, a backward hinge instead of on the leading edge of the control, and the Avro balancing plane above an aileron as fitted in the "Manchester." Of these three the backward hinge became standard practice. The importance of the effect of the gap between the nose of the aileron and the wing and the shape of the nose in the gap were stressed and much has been done in these matters since that date. Irving conducted many more wind tunnel experiments on this subject and put forward in November 1939, a proposal for a shrouded nose balance to avoid the gap effect.

Messrs. S. B. Gates and L. W. Bryant wrote a monograph on the spinning of aeroplanes in October 1926, and also lectured to the Society in March 1927 on the subject. Although Irving published a paper on the effect of stagger and decalage on the auto-rotation of a biplane in September 1920, he did not undertake other work on spinning until he published in November 1926, "Experiments on a model of the B.A.T. Bantam with special reference to spinning accidents." Many other papers followed, culminating in the second lecture to the Society on spinning which he gave in November 1931 with A. V. Stephens of the Royal Aircraft Establishment. Entitled "Safety in Spinning" it summarised the progress made in the intervening four and a half years, both in theory and in full scale and model tests. For the first time attention was drawn to the importance of the difference between the rolling and pitching inertias of

aeroplanes in relation to spinning, due to the loading up of the fuselage in those days without at the same time spreading loads on the wings. The paper was welcomed by a well-known chief designer for its clarification of ideas as to the causes and the prevention of spinning. A feature of the occasion was a demonstration of freely falling models in a vertical wind tunnel set up on the dais.

In the early summer of 1939 Irving was chosen to start a new experimental research station on stability and control at Duxford. To this end his long association with the N.P.L. was severed and he was transferred to the Royal Aircraft Establishment at Farnborough, but the outbreak of war frustrated the intention, so he remained to do wind tunnel work at that establishment. When hostilities ended, he was posted to the Ministry of Supply in London, becoming Assistant Director of Research (Air) until he retired in 1954.

While at the ministry he was responsible for initiating in 1950 researches on the reduction of noise from jet engines, a subject which engaged his interest for the rest of his life, first as a consultant to the ministry from 1954-57 and then as consultant to Bristol Siddeley Engines Ltd. and Westland Aircraft Ltd. During part of this time he was Chairman of the Noise Research Committee as well as a member of other committees of the Aeronautical Research Council.

Irving's main contributions to aircraft noise were firstly his appreciation that this was an important problem on which research was essential and secondly, on his certainty that this was a problem that could be tackled by the universities as well as at firms. His persuasiveness and encouragement to all the English universities on the noise problem played no small part in the relatively successful efforts made ultimately in this country and overseas on the noise reduction from jet engines both on the ground and in flight. He set up the meeting of Noise Researchers, from 1950 onwards attended by both university workers and members of firms; it was by way of his invitation in 1953 to workers in the United States to attend these meetings, that the States became aware of the problem and the progress made in this country. From that time onwards the two-way exchange of visits and invitations was found to be most profitable in the development of the subject. A recent letter from Langley Field draws attention to this, "I think that many of us feel a debt of gratitude to you for your labour in promoting noise work in U.K. and U.S.A. and look on this Agardograph (which Irving was editing) as a somewhat belated personal acknowledgment." In addition to jet noise, Irving took an increasing interest in the noise from helicopters and wrote a paper on this subject which was presented to the Helicopter Association.

He was Chairman of a little-known body, the Low Speed Aerodynamics Research Association, which had come into being to find out more about flight at very low speeds. In that capacity he attended the historic meeting at Cranfield in January 1957, at which MAPAC was founded, internationally known today as the Man Powered Aircraft Group of the Royal Aeronautical Society. This absorbing interest remained with him to the end and he wrote an article, while lying helpless on his back, which was published in *The Aeroplane* on 4th November 1960. In this subject he took on the role of encouraging others to work in this field and helped in no small measure to co-ordinate their respective efforts. The small amount he wrote was in no way a measure of his achievement in this as indeed in his many other activities. He himself gave generously to the cause of man powered aircraft and he donated all he received from articles and T.V. programmes to the Man Powered Aircraft Fund. He encouraged others to do likewise and if Man Powered Flight in the sense we know it, is achieved, it will be a fitting memorial to one who had the courage to hold the torch and to persuade the sceptics that here was a scientific experiment of sufficient complexity to tax the energy and resources of aerodynamicists, aeronautical engineers and designers of the present day and age.

Mr. Irving was elected an Associate Fellow of the Society in February 1917 and a Fellow in 1932. He was a past Chairman of the Society's Aerodynamic Data Sheets Committee, Chairman of The Man Powered Aircraft Group, and a visiting lecturer to the College of Aeronautics.

Throughout his life Irving was a very sociable person, engaging in several athletic sports in his earlier years and developing into a keen and successful gardener in his later years. His hospitality in a delightful house and garden at Cobham, Surrey, has been enjoyed by many. He was a man of great personal charm, kindness and sincerity and his strength of character and integrity were an inspiration to all who knew him. He will be greatly missed by his widow and daughters, by his friends of all ages and by his many business friends in this country and in the United States of America.—J.L.N.

Ten Economic Lessons from Short-Haul Airline Operations

BY

STEPHEN F. WHEATCROFT, B.Sc.(Econ.), A.F.R.Ae.S.

The 1,179th Main Lecture to be given before the Society—and the first Main Lecture to be given in the new Lecture Theatre—"Ten Economic Lessons from Short-Haul Airline Operations," was given by Mr. S. F. Wheatcroft, B.Sc.(Econ.), A.F.R.Ae.S., on 15th December 1960. Mr. P. G. Masefield, M.A.(Eng.), F.R.Ae.S., Hon.F.I.A.S., Immediate Past President, presided.

Before introducing the Lecturer, Mr. Masefield said that this was an auspicious occasion because this was the first Main Society Lecture to be held in the Lecture Theatre. Although he was sure there was nobody better fitted than Steve Wheatcroft to give this first lecture and no more valuable subject than the economic lessons from short-haul airline operations, Mr. Wheatcroft unfortunately had let the side down by not requiring any of the modern push-button equipment which was a feature of the Lecture Theatre.

Steve Wheatcroft was known to everybody in air transport, not only in this country but all over the world, where he spent half his time when he was not advising B.E.A. on what *not* to do. Mr. Wheatcroft obtained his B.Sc. degree with first class honours in economics at the London School of Economics in 1942. After the war, during which he served as a pilot in the Fleet Air Arm, he returned to the London School of Economics, taking a Leverhulme Post Graduate Studentship and studying, in particular, the economics of air transport. He was appointed Economic Adviser to British European Airways in 1946 and subsequently joined the Commercial Department as Manager in charge of Research and Tariffs. In 1953 he left the Corporation to go to Manchester University as a Simon Research Fellow and wrote a book called "The Economics of European Air Transport". Wheatcroft on "The Economics of European Air Transport" was still a standard and was rapidly becoming a classic work. Since 1954 he had acted as a Consultant and had been retained as Economic Adviser to British European Airways. In 1958 he was commissioned by the Canadian Government to make a study of the desirability and economic consequences of trans-continental competition and his report, "Air Competition in Canada," was published in June 1958. In 1959 he was appointed Chairman of a Committee set up by the Government of India to investigate the cost structure of the Indian Airline Corporation. More recently he had been a member of the Tymms Committee to the West Indian Government to advise on civil air policy in the West Indies, and now, he was about to go to Nigeria to tell them how to do it.

Introduction

During the past few years I have been involved in studies of air transport operations in various parts of the world: Europe, Canada, India, Central Africa, The West Indies and Nigeria. Some of these studies have been made on behalf of governments, others on behalf of airlines. But each of them has had in common the characteristic of being concerned primarily with relatively short-haul operations within a limited geographical region. For this reason I have thought it worth while to attempt in this lecture to summarise what appear to me to be the ten most important economic lessons to be learned in this particular field of airline operations. It occurs to me, too, that as aeroplanes fly faster and faster the long-haul airlines are increasingly brought up against the problems which have beset short-haul operations in the past. These economic lessons from short-haul airline operations may therefore have a wider relevance than the regional field.

LESSON 1

HIGH ROUTE TRAFFIC DENSITY IS THE KEY TO LOWER COSTS AND PROFITABLE OPERATIONS

It is still commonly held that short-haul airline operations are inherently less economic than long-haul. This is, I think, an over-simplification, and one which may be dangerous for airlines and governments in the formulation of air transport policy in the present stage of the industry. The belief that it is easy to make money in long-haul operations, and that the profits derived from these operations can be used to cover the losses that inevitably arise from short-haul operations, consciously or unconsciously still colours a good deal of thinking about air transport development.

The Commission on Civil Aviation in the West Indies,[1] on which I recently served under the chairmanship of Sir Frederick Tymms, found that this view had strongly influenced West Indian thinking about the future operations of their national airline. The Commission concluded that there were two flaws in the argument so far as it concerned the West Indies: firstly, it thought that a West Indian national airline would probably lose money on the proposed long-haul operations, and secondly, it could see no reason why short-haul services within the Caribbean region should not be made profitable. It is beyond the scope of this paper to discuss the reasons why we thought that the proposed West Indian long-haul services would be unprofitable. I will just say in passing that the vastly increased productivity and complexity of large, long-haul jet aircraft make it increasingly difficult for small airlines to compete successfully in inter-continental operations. As for the second of the Commission's conclusions, most of this lecture will be concerned, one way or another, with the reasons why it ought to be possible to operate profitably on short-haul routes like those within the Caribbean basin.

But let me return to my original statement and explain why I think it may be fallacious to think that short-haul operations are inherently less economic than long-haul. It is generally true that short-haul services are inherently more expensive to operate than long-haul. But when we use the word "economic" we refer (or ought to refer) to the relationship between costs and revenue. My argument is that this relationship is not necessarily and inherently worse for short-haul operations than for long-haul. I am not arguing that the reverse is true—that short-haul services are inherently more economic than long-haul. What I want to suggest is that there are a number of other factors which are just as important as length of haul in the economics of airline operations, and that these factors may often be favourable in short-haul operations, thus offsetting the inherently high cost features of short-stage routes.

The most important factor which I have in mind here is route traffic density. By this I mean the average volume of traffic on each route flown by the airline. This, without doubt, is one of the most vital factors in air transport economics. Route traffic density is the factor which determines the size of aircraft and frequency of service operated by the airline: and the economic importance of large size and high frequency is well established. Route traffic density also has a major influence on the average utilisation (or throughput) of stations and this is a further important factor in determining the level of airline costs. It is by exploiting these advantages that short haul services can be operated profitably.

In the study of economics it is rarely possible to offer precise proof of any thesis. We attempt the scientific process by way of observation to hypothesis and by testing to theory. But there are almost always too many variables in each situation to enable a 100 per cent proof to be offered of precise cause and effect. I say this because I am aware that the example I am going to show of the relationship between high route density and profitability is open to the objection that the causal factors may be quite other than the one I am suggesting. I therefore present the following case not as a proof but as an illustration of what I believe is a basic causal relationship in air transport economics.

My illustration is the progress which B.E.A. has made on the trunk domestic routes London-Glasgow and London-Edinburgh in the past six years. The economic development of these London-Scotland routes is described in Fig. 1 which shows:

(*a*) the great increase in the capacity operated by B.E.A. on these routes in the past few years. Output has increased fivefold from just over 4 million CTM (Capacity-ton-miles) in 1954/55 to almost 20 million CTM in the current year.

(*b*) the fall in the operating cost per CTM which has been associated with the increase in route traffic density.

(*c*) the overall load factor which has been achieved and the effect which this has had when one converts the expenditure from a CTM basis to an LTM basis (so that expenditure and revenue per unit of output can be directly compared).

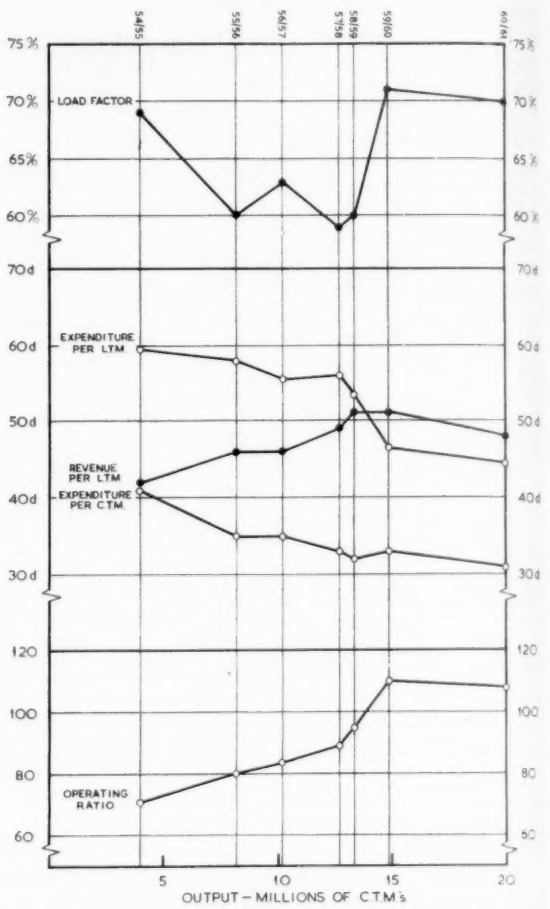

FIGURE 1. Analysis of B.E.A.'s economic development of London-Scotland routes.

(*d*) the level of the revenue rate per LTM—showing a tendency to rise over the early part of the period, because of the increasing importance of first class traffic, but tending to fall in the past two years.

(*e*) and finally, profitability, as measured by the operating ratio each year. (This is

$$\frac{\text{revenue}}{\text{expenditure}} \times 100$$

and is a simple expression of the relative financial success of the routes each year. I would like to suggest in passing that consideration be given to calling this The "REVEX ratio")

You will observe in Fig. 1 that, in the first year plotted, the London-Scotland routes required a load factor of almost 100 per cent to break even. At an achieved load factor of 69 per cent the revenue earned only covered 71 per cent of total costs. As the route traffic density has increased so has the financial position improved, and in the past two years the London-Scotland routes have been transformed from an economic liability to a profitable part of B.E.A.'s operations.

It may be objected that it was the high level of load

factor and not the increase in route traffic density which was the primary reason for profitable operations in 1959/60 and 1960/61. I take the view, however, that the high load factor was itself causally related to the high traffic density (even though this may appear to be contradicted by the high load factor achieved in 1954/55). I will have more to say about this question shortly, particularly about the relationship between load factor and frequency of service. At this stage I will merely point out that frequency on the London-Glasgow service increased from four daily (one Viscount and three Viking services) in the summer of 1954 to ten Viscounts daily in the summer of 1960. The frequency of the London-Edinburgh service increased from two daily (one Viking and one Dakota service) in the summer of 1954 to six Viscounts daily in the summer of 1960. This is, perhaps, the best way of describing the revolutionary change in the route traffice density and economic status which took place on the London-Scotland routes in the period illustrated in Fig. 1.

If it is true, as I believe, that high route traffic density is a major factor in leading to lower costs and profitable operations, many important conclusions follow from this for governments, as well as airlines, in the formulation of future policies. I suggested some years ago in *The Economics of European Air Transport* that "the most urgent European need is for a system of economic regulation which is directed towards lowering operating costs by creating the condition of intensive expansion."[2] Although air transport in Europe has made a good deal of progress since those words were written I still hold the statement to be true. And I believe it to be valid not only for European operations but also for short-haul regional operations in other parts of the world.

LESSON 2
HIGHEST PRACTICABLE LEVEL OF OPERATING UTILISATION IS ECONOMICALLY VITAL

I acknowledged earlier that although short-haul operations should not be regarded as inherently less economic than long-haul, they do tend to be more expensive to operate. One of the major reasons for this is that aircraft productivity is usually lower on short routes than on long, and this for two reasons:

(*a*) the influence of lower block speed on shorter routes causes the hourly productivity (CTM per aircraft hour) to be lower;

(*b*) the difficulty of achieving as high aircraft utilisation on short routes as on long—because time on the ground for transits and turn-rounds is a greater proportion of the working day—causes annual productivity (CTM per aircraft per annum) to be lower.

The effect of these two influences, taken together, may easily mean that the same aircraft, if operated on a route network with an average stage length of 250 miles, would have an annual productivity as much as one third lower than if it were operated on a network with an average stage length of 1,000 miles.

The economic consequences of this influence of stage length on aircraft productivity means that the short-haul airline must pay great attention to ensuring that utilisation is kept at the highest possible level which is practicable from an operating and commercial point of view. This is, of course, well known and generally accepted. But what I think is often overlooked is that this may remain true even when the aircraft in question have been written down to a very low, or nil, value in the airline's balance sheet. One sometimes hears it said that utilisation is not important when aircraft—like the DC-3—are completely written off in an airline's books. Depreciation and interest may, indeed, be ignored in these circumstances and insurance may be very low. But there are often other costs which, being a cost per aircraft—per day or per year—will be influenced by aircraft utilisation.

The study which a committee under my chairmanship made of the Indian Airlines Corporation provided an interesting example of this situation.[3] When the study was made in 1959, IAC had a fleet of 42 passenger Dakotas in active service. Of these 42 aircraft only 25 were actually required to fly the services each day, the balance being aircraft in maintenance or held as reserve cover. Hence, although the rate of utilisation of aircraft actually flying each day was not unduly low, the average utilisation for the whole Dakota fleet was very low. Moreover, although the IAC Dakotas were mostly written down to nil value and no insurance premiums were paid for these aircraft, the effect of this low average utilisation on the cost level was nevertheless quite significant. The reasons were, firstly, because a high proportion of maintenance costs, like the costs of their 12 monthly and 24 monthly C of A overhauls, as well as the costs of daily maintenance inspections, were "fixed per aircraft costs" for specific periods of time. Hence, the level of these costs, per unit of output, was directly related to aircraft utilisation. The second, and perhaps more unusual, reason was the influence of aircraft utilisation on fuel consumption. The Committee found that IAC Dakotas were using about 20 gallons of petrol per aircraft per day in the course of daily maintenance (including the fuel used while running up the engines). This fuel was used not only by the aircraft actually required for flying each day but also by the aircraft on reserve and stand-by duties. Because, as already mentioned, the number of reserve aircraft was a high proportion of the total, the fuel used in maintenance was accounting for four or five gallons per hour of IAC's average Dakota consumption—a material cost consideration for an airline which is obliged to pay 4s. 6d. per gallon for petrol. The Committee suggested that IAC's fuel bill and maintenance costs could be significantly reduced if it increased its average aircraft utilisation by taking out of service the Dakotas surplus to operational requirements.

There are other ways in which aircraft utilisation may influence an airline's cost level but I think that this example serves well to illustrate my point that a short-haul airline must take special care to ensure that its utilisation is as high as practicable. And although I have been speaking here only about aircraft utilisation, what I have said is equally true of achieving the highest practicable level of air crew utilisation.

LESSON 3
HIGH ROUTE TRAFFIC DENSITY MAKES POSSIBLE HIGH LOAD FACTORS WITHOUT REPRESENTING INADEQUATE PUBLIC SERVICE

When discussing the results which B.E.A. has achieved on the London-Scotland routes I suggested that there was a causal relationship between route traffic density and load factor. I now want to explain why I think that this is true.

The load factor which an airline achieves on any route depends upon a large number of factors. Chief among these are:

(*a*) the accuracy of its traffic estimates, in detail as well as in total;

(*b*) the skill it uses in matching aircraft capacity to the available traffic—particularly when there are unforeseen variations in demand;

(*c*) the effectiveness of its reservations system and its skill in anticipating the pattern of bookings, cancellations, no-shows, etc.

But over and above these considerations there is always the question of the level of load factor which the airline is aiming to achieve. The foregoing factors will merely determine how successful the airline is in meeting its target. The question I want to discuss here is the desirable level of load factor at which the airline should aim.

The thesis which I want to argue is that as route traffic density increases it becomes possible for an airline to aim at a higher average load factor without, in the process, reducing the standard of service offered to the public. The average load factor which an airline ought to set out to achieve on each route, it seems to me, is the highest level at which the maximum commercially acceptable risk of turning traffic away is reached. It should be possible to assess this risk by analysing the percentage of occasions on which would-be passengers are likely to be turned away at any given level of average load factor for any period of time. Let us look at the method for carrying out such an analysis.

I have illustrated my own approach to this problem in Fig. 2. The first requirement is for a generalised analysis of load factor distribution on individual flights around a given average for a period of time. The distributions which I have illustrated in Fig. 2 were arrived at after studying results on a number of B.E.A. routes. At lower average figures than those illustrated more complex variations are possible because of the complications of factors like directional traffic movements. But at the higher average load factors depicted in Fig. 2 there is good reason to believe that the pattern shown—or something like it—will have a general validity for all airline operations. (Even if the pattern which I have illustrated is not precisely correct there is no reason for thinking that more accurate curves could not be derived.) The pattern of load factor distribution has been shown in Fig. 2 in the form of a cumulative percentage curve for each average. Suppose we are considering a route on which the average load factor for the month was 80 per cent. The distribution curve suggests that on 92 per cent of occasions the load factor on individual flights was higher than 50 per cent; on 64 per cent of occasions the load factor on individual flights was higher than 80 per cent; and on 10 per cent of occasions individual flights were 100 per cent full. Information of this kind is the first step in the establishment of an acceptable average load factor.

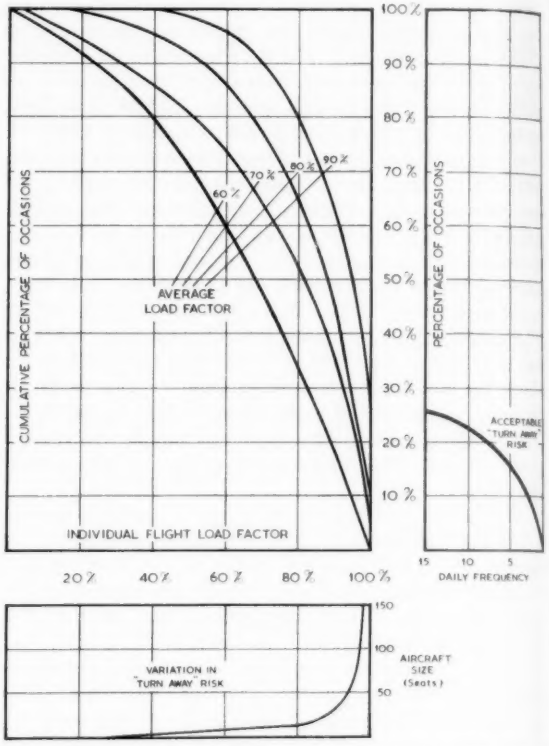

FIGURE 2. Influence of frequency of service and aircraft size on achievable load factor.

The second step is to consider the point at which would-be traffic may be turned away. Here the average size of a booking group is a material factor. The existence of one unbooked seat on each flight may not be enough to guarantee that traffic is not being turned away if the average booking group (people wishing to travel together) with which the airline has to contend is three or four. In establishing its acceptable load factor the airline must therefore consider the percentage of occasions on which it will not be able to accommodate its average booking group. Having said this, it is clear that the size of aeroplane used now becomes a significant variant in the analysis. If, as I have assumed in preparing Fig. 2, the average booking group is three people, the cushion required to ensure that these can be accommodated will represent six points of load factor in a 50 seat aeroplane, three points of a load factor in a 100 seat aeroplane, and two points of load factor in a 150 seat aeroplane. The larger the aeroplane, therefore, the higher is the load factor at which the risk of turning away passengers occurs.

The third, and last, step in the analysis is to make a judgment on the percentage of occasions which is commercially acceptable that would-be passengers may be turned away. Managements will have their own

views on this question and the same management may have different views about it at different times, according to the prevailing circumstances of the airline. In some circumstances it may be thought reasonable that a one in ten probability of turning traffic away is commercially acceptable: in other circumstances a lower probability may be chosen. But in making this choice the management must be particularly influenced by the frequency of service which the airline operates on the route in question. If only a weekly frequency is operated the airline will be obliged to accept a very low risk of turning traffic away. If, on the other hand, the airline is operating 10 flights each day, like B.E.A. between London and Glasgow, the management may reasonably conclude that a much higher risk of turning away traffic on a particular flight is quite acceptable because if passengers cannot get seats on the flight of their first choice they will probably, without hardship or complaint, accept accommodation on another flight within an hour either way of that first choice. I have therefore illustrated in Fig. 2 a curve showing the possible relationship between daily frequency of service and the commercially acceptable turn away risk.

It is because both aircraft size and daily frequency of service are obviously related to route traffic density that I have ventured to suggest that there is a direct causal relationship between load factor and traffic density. And to conclude this section it may be worth taking an example from Fig. 2 to illustrate the sort of load factor which might reasonably be achieved on a route of high traffic density. Let us look at a case where an airline is using a 100 seat aeroplane and is operating 10 or more services daily. With an average booking group of three the turn away risk arises when the load factor on individual flights exceeds 97 per cent. The airline may, however, think it reasonable, with such a high frequency, to accept this risk at a level between 20 and 25 per cent of occasions. In this case it would be justified in planning to achieve a route load factor of 80 per cent. This is a far cry from the idea that 65 per cent is in some mysterious way a good target load factor in airline operations.

LESSON 4
FLEXIBILITY IN THE DISPOSAL OF PAYLOAD HAS AN IMPORTANT BEARING ON THE ABILITY OF AN AIRLINE TO ACHIEVE HIGH LOAD FACTORS

Before leaving the subject of load factor there is another aspect of this question which I think qualifies to be regarded as a major economic lesson from short-haul airline operations. The previous section of this paper was concerned with passenger load factor. Equally important for the airline is the overall revenue load factor achieved, the relationship between load-ton-miles of all categories of traffic and the capacity-ton-miles operated. An airline which is achieving a high passenger load factor but a substantially lower overall load factor is operating less efficiently than it ought to be, for it always costs something to carry around unused potential payload.

I drew attention to this problem in *The Economics of European Air Transport* some years ago, and I demonstrated that the main reason for the significant difference between passenger and overall load factor in European operations was the fact that the internal configuration of the aircraft then used did not allow maximum payload capacity to be used entirely for the carriage of passengers and their baggage; the aircraft used had a substantial deadload capacity in excess of full passenger payload. This fact was of particular importance because of the seasonal traffic variation in European passenger traffic. Much more capacity is operated in the summer months than in the winter in order to satisfy the peak passenger demand. But because there is no corresponding seasonal variation in the demand for freight and mail capacity, these additional summer flights meant that additional and unwanted cargo capacity was also provided during the summer. It was this unwanted summer deadload capacity which was the main factor in causing the gap between passenger and overall load factor in European operations.

In B.E.A.'s operations in recent years there has been an improvement in the relationship between passenger and overall load factor, and indeed, in 1959/60 the two were almost identical on international routes. The international passenger load factor was 67·6 per cent for the year and the corresponding overall load factor was 67·5 per cent. The closing of the gap between these two figures was largely due, I think, to the fact that the Viscount fleet—after the conversion of the V701 to high density seating—approached closely to the ideal of being able to carry all payload in passenger form. At the same time the Viscounts had a good deal of flexibility in the disposal of their payload so that freight traffic could be carried whenever the demand existed.

Whenever an airline is faced with variations in the pattern of seasonal demand for different types of traffic it will only be able to achieve a high overall load factor if the aeroplanes it uses offer considerable flexibility in the disposal of their payload, and the ability to carry all payload in passenger form is an essential feature of such flexibility. Aircraft designers are inclined to take the view that this demand for flexibility is just another sign that the airline—and the commercial department is usually blamed—cannot make up its mind what it wants. The fact may be that the airline does know what it wants—if it really needs an aircraft which can be changed as quickly as possible from carrying its payload in different proportions. And this demand for maximum flexibility now applies to the proportion of passengers in different classes of service as well as to the proportion of passengers to deadload traffic. A lot of new thought has got to go into seat design to achieve this objective. This flexibility is of tremendous economic importance to the airline and its value can be measured, as I have already said, by the difference between the overall and passenger load factors.

LESSON 5
MAXIMUM FLEXIBILITY IS ESSENTIAL IN AIRLINE PRICING POLICY

In the formulation of airline pricing policy—particularly on the passenger side of the business—there is always a conflict between the economist and the sales-

man. The salesman wants a simple tariff, and it must be accepted that selling is easier—and, therefore, more effective at a lower cost—if there are few complications in the pattern of fares. But the overall economic advantages which the airline derives from a more complex fares structure may far outweigh the benefits of tariff simplicity. It is one of the most important jobs of airline management to hold the correct balance between economic and selling arguments in the formulation of tariff policy.

It is something of a digression but it is interesting to note that Professor Paul Cherington in his book *Airline Price Policy*[4] suggests that top management of airlines in the United States have paid too little attention to questions of tariff policy and certainly have never given these questions anything like the same amount of consideration as they have devoted to equipment policy. Moreoever, he is not convinced that the airlines have adopted a sufficiently scientific approach to price determination. He suggests that "the feel of the market" has been a more general guide than detailed analysis of existing and potential traffic. I venture to suggest that these strictures are much less justified in the European airline business. Indeed, what have often been criticised as undue complications in the European fare structure ought more properly to be regarded as evidence of the airlines' willingness to experiment with new types of fares and to test the elasticity of the market in the most effective practical way.

But I must now return to the main theme, the particular importance of flexible tariff policy in short-haul operations. There is no inherent reason why the traffic pattern on short-haul routes should be more complicated than on long; no inherent reason why traffic should be more peaky at different times of the year or the week, or more sensitive to different kinds of fare inducements. But certain short-haul regional operators have, in fact, faced these problems in a much more acute way than have long-haul airlines. The experience of these short-haul airlines will become more interesting to those in the long-haul field as inter-continental traffic increasingly adopts, as evidence already indicates, the same sort of uneven demand characteristics which are so familiar, for example, in the European short-haul market. The important lesson from short-haul experience is that price policy can have a major influence on the pattern of air traffic demand and can direct it in ways which greatly improve the economy of airline operations.

One of the most remarkable features of B.E.A.'s results in 1959/60 was that it achieved an average passenger load factor of 69·4 per cent over the whole year. To a very large extent this result was made possible by the complicated system of fare differentials which B.E.A. has developed in Europe. In the words of *The Economist*, B.E.A. has "bribed passengers to go to places and to travel at times they would not normally have chosen without a financial inducement."[5] This may not sound flattering but I think that it was meant kindly.

The fact that B.E.A. has been able to develop such a complex system of fares in Europe—and it is indisputable that B.E.A. has been the price leader in this area—throws an interesting side light on the way in which the I.A.T.A. rate-fixing machinery works. We are told so often that this is a rigid international cartel which leaves no room for individual airlines to manoeuvre prices to meet the particular needs of their own markets, that people, even within the industry, sometimes come to believe that this is true. An airline which really knows what it wants, and why it wants it, can almost always get its tariff policies adopted at the Traffic Conferences. It is often hard work, and requires a lot of "lobbying" before the Conferences meet, but it can be done. And I think that the complexities—let us call them refinements—of the European fare structure prove this to be true.

If I have dwelt unduly on the European fare structure in this part of my paper it is because I believe that more progress has been made in the intelligent use of flexible tariff policies in Europe than in other parts of the world. In the other regional operations with which I have been concerned in the past few years the need for this kind of flexibility in pricing is a message which I have constantly preached. I hope that Central African Airways will forgive me if I quote two or three lines from the report which I prepared for them earlier this year:

> "I do not think that there is any economic justification for having a standard rate per mile for basic fares, and I think that there are very good reasons for using promotional fares to the maximum possible extent to overcome the problems created by variations in the pattern of demand."

I was, as a matter of fact, offering this advice to a receptive customer because Mr. Max Stuart-Shaw, the General Manager of Central African Airways, had earlier been responsible for several important innovations in the European fare structure when he directed the commercial policy of Aer Lingus.

To conclude this section of the paper I think it is desirable that I should say a few words about the theoretical justification for fare differentials and to dispel the notion that these always involve an element of unjust discrimination. In many parts of the world there is a strong tendency for governments to take the view that the best and fairest fare structure is one based on a standard rate per mile for all routes. Any departures from this are viewed with concern, particularly by those government agencies which are charged with ensuring that fares do not involve unreasonable preference or unjust discrimination. It is fairly easy to demonstrate that when significant differences in costs occur on different routes, or in different classes of service, or at different periods of time, fares ought to reflect these cost differences. I will come back to this point in the next section. It is more difficult, however, to get across the idea that true discrimination—by which I mean charging different sets of people different fares for precisely the same service—may often be good social policy as well as good commercial policy.

Fares for inclusive tour passengers are a good example of this case. These fares are discriminatory in the sense that I.T. (Inclusive Tour) passengers may travel at reduced rates on the same aircraft and get the same service as passengers paying the full fare. The issue is whether discrimination of this kind is justified—is it

just or not? The Civil Aeronautics Board in the United States has held that this is unjust discrimination and will not permit discounts to be granted for I.T. purposes. I think that the Board is wrong in the stand it has taken on this issue. And to explain why I must refer back to the first lesson propounded in this paper: an increase in route density leads to a fall in the average level of operating costs. If average costs are falling then marginal costs are lower than average costs, (this is first-year economic theory). It follows from this that if the fare charged to I.T. passengers is not less than the marginal cost of providing service to them, and if the fare reduction is genuinely promotional, creating new traffic which would not otherwise have travelled, the result of price discrimination will be that the average cost level is reduced and all users of the service may be better off. Note the point—the normal full-fare passenger may be paying a lower fare than otherwise because of the reduction in the average cost level which the discriminatory fare has made possible. It is this kind of approach which ought, in my view, always to be the test of whether any fare is justly or unjustly discriminatory.

LESSON 6

CROSS-SUBSIDISATION OF UNPROFITABLE OPERATIONS BY PROFITABLE SERVICES IS A DANGEROUS POLICY—COMMERCIALLY AND SOCIALLY

I remarked in the previous section that where there are significant differences in costs for different routes or types of services these ought to be reflected in the fares charged. This is by no means a universally accepted view in the economic regulation of air transport: governments generally favour the simpler solution of a standard rate per mile. But it must be recognised that any departure from the principle which I have stated means that there will be cross-subsidisation within the operations of the airline. And it must also be recognised that cross-subsidisation of this kind can have dangerous economic consequences.

From an economist's point of view the main argument against internal cross-subsidisation is that it may easily lead to a faulty allocation of resources. A market economy only works effectively if prices are related to costs and if firms expand profitable lines and contract those which are unprofitable. If prices are not related to costs the market is thwarted in its process of determining the outputs which consumers prefer. There may be cases when it is right and proper for the government to over-ride the working of the market and to subsidise particular goods or services. But if it is thought desirable for national and social reasons that certain products should be subsidised, it is almost invariably good social policy to pay a direct subsidy for the production of those things. I was pleased that this view was adopted by the Select Committee on the Nationalised Industries in their report on the Airways Corporation in 1959.[6] The Committee recommended that direct subsidy should be paid to the Corporations for any routes which they operated as a matter of social obligation and which were unlikely to be profitable in the foreseeable future, and cited the social services operated by B.E.A. in Scotland as an example of where such subsidy would be justified. As an economist I, personally, think that this is a sound recommendation, and it is a matter of regret to me that this view is not now shared by the Board of B.E.A. The Corporation's view is that it would prefer to be entirely free of subsidy—with the political interference that this involves—while it is able to bear the losses of its social routes from other profits. It takes this view partly because it thinks that the stigma of being subsidised has a bad effect on staff morale. This is a reasonable point of view for the airline to take and, as a matter of fact, the social routes are a sufficiently small part of B.E.A.'s total output for there to be no great danger of misallocation of resources.

In other cases, however, where cross-subsidisation exists on a larger scale, the consequent economic problems can be serious. The domestic airline situation in Canada provides a good example of several of these problems. When I studied this situation in 1958, in the course of preparing my report "Airline Competition in Canada,"[7] I found that the profits which T.C.A. made on the trans-continental routes were largely going to cover the losses, amounting to almost $3 million a year, incurred on lesser traffic routes of social rather than commercial importance. Moreover, the other traditional element in such situations was also present—a predilection for a standard rate per mile in the fare structure.

When Canadian Pacific Airways applied for rights to operate a competitive trans-continental air service, T.C.A. protested that the effect of this would be to reduce or eliminate the profits on which it relied to support the social services. And this is, indeed, the major commercial danger of a policy of cross-subsidisation: an airline pursuing such a policy will always be vulnerable to competition on its profitable routes.

One of my recommendations in Canada was that the Government should abandon its policy of requiring T.C.A. and other airlines to accept obligations to support unremunerative socially desirable routes and should adopt instead a system of direct subsidy for these routes. I further suggested that consideration should be given to the transfer of these services, on a subsidised basis, to regional airlines specialising in this sort of secondary route operations. My thought was that carriers of this class would probably not need as much subsidy as T.C.A. because they would not be obliged to operate these secondary routes to mainline quality standards.

My third recommendation on this same general subject was that T.C.A. should reconsider its fare structure, bearing in mind the objective that charges should be based to the greatest possible extent on the costs of providing the specific services concerned. The point which particularly concerned me was that "the fare levels on the major trans-continental routes are higher than their costs warrant" whereas "on other routes there is some evidence that the fare levels are lower than dictated by costs and, judging by the load factors achieved, lower than necessary from a competitive point of view."[7] The most unfortunate result of this tariff policy was that the rate of traffic develop-

ment on the major trans-continental routes, where traffic is probably more sensitive to fare reductions than anywhere else, has to some extent been retarded by higher-than-necessary fares.

Since the time that I made my Canadian study there have been a number of developments in Canada which I find encouraging. T.C.A. has been obliged by the limited competition from C.P.A. on the trans-continental route to reduce the extent of its internal cross-subsidisation. It is attempting to rid itself of some of its most troublesome secondary routes, and in particular it wants to transfer to a regional carrier the Prairie route which goes from Calgary to Winnipeg via Lethbridge, Medicine Hat, Swift Current, Regina, Yorkton and Brandon. It must be sad to contemplate giving up a route with such poetic and romantic names but it is a particularly difficult route for T.C.A. because it is the only one in the system which still requires DC-3s for its operation. For this reason alone there is much to be said for having a regional carrier take over this route from T.C.A. But, so far, the reluctance of the Canadian Government to offer a subsidy for its operation has proved a barrier to this solution.

Another development in Canada which I find encouraging is the comprehensive revision of the T.C.A. fare structure which has recently been announced. With effect from 2nd January 1961 T.C.A. intends to reduce all fares on trans-continental flights of more than 600 miles by up to 25 per cent. At the same time it intends to increase the fare level on many of its secondary and shorter routes. I am quite sure that T.C.A. is right to have adopted this policy, not least because it is a move towards the elimination of all cross-subsidisation in the airline's economic structure.

LESSON 7

COMPETITION IS A DOUBLE-EDGED SWORD

The advantages and disadvantages of airline competition is a large subject which I can only discuss briefly in this paper. In saying that competition is a double-edged sword I am quoting from the conclusions reached by Messrs. Gill and Bates in *Airline Competition*[8]—a comprehensive study of the United States domestic industry published in 1949. My own investigations have led me to the same general conclusion: that there are some circumstances in which airline competition may have beneficial results—better service to the public, more efficient and lower cost operations, and so on, but in other cases, competition can be financially damaging to the airlines and fail to provide better public service.

You will have gathered from what I said in the previous section that I do not regard it an argument against competition that it makes it difficult for an airline to support unremunerative services. I do not think I need to say more on that subject. On the other hand, I must make it clear that all that I say in this section refers to a very limited conception of competition: a striving for traffic between the airlines within the bounds of a system of economic regulation of the industry which includes a control of entry by route licensing.

The circumstances in which competition may or may not be beneficial depend, I think, on two factors:

(*a*) the level of traffic on the route in question

(*b*) the extent to which the traffic is split between competing airlines.

Dealing with the second of these points first, I will only say that I entirely accept the conclusion reached by Gill and Bates that all the claimed advantages of competition can be achieved by having two airlines on a route: the addition of a third, fourth or fifth airline does not contribute greater public advantage but it does create further economic difficulties by the undue splitting of traffic between carriers.

To establish the traffic level needed on any route before competition is likely to be beneficial (or below which it is almost certain to be harmful) is a difficult but important question in the economic regulation of the industry. It will, I think, be essential for our new Air Transport Licensing Board to form a judgment on this question to guide them in their consideration of the applications which will soon be coming before them. One of the main objectives of my report "Airline Competition in Canada" was to try to answer this question and I propose now to summarise the conclusions which I reached in 1958.

My approach to this question starts from the first proposition advanced in this paper; that there is an inverse relationship between the level of costs on a route and the density of traffic. We must be clear, however, that this relationship applies to a particular airline operating a route. That is to say, if there are two or more airlines operating the same route they each experience a fall in their average cost level as their traffic increases but they only benefit to the extent of their own traffic volume, not to the extent of the total traffic volume on the route. This being so the licensing board must compare the probable costs level if one airline is allowed exclusive rights on the route with the alternative of two carriers, each probably operating at a somewhat higher cost level, because of their lower traffic volumes, but with a greater incentive to efficiency because of the competitive stimulus. The greater the total traffic volume on the route the smaller will be the gap between the two cost levels under consideration and, hence, the stronger will be the presumption that competition will be beneficial.

My own calculation of the traffic level at which this presumption is likely to be valid was based on the conviction that route traffic volume affects the level of operating costs most directly by its influence on the frequency of service and the load factor achieved. If this is true, and it is also possible to establish the frequency of service which each competing airline thinks it is commercially desirable that it should operate on routes of different lengths, then the traffic volume required for competition can be calculated quite simply if a further assumption is made about the size of aircraft which will be used. This is what I did in the Canadian report and the results arrived at are illustrated in Fig. 3.

For any given length of route the traffic volume required to support a competitive service can be read off against the probable size of aircraft which the competing

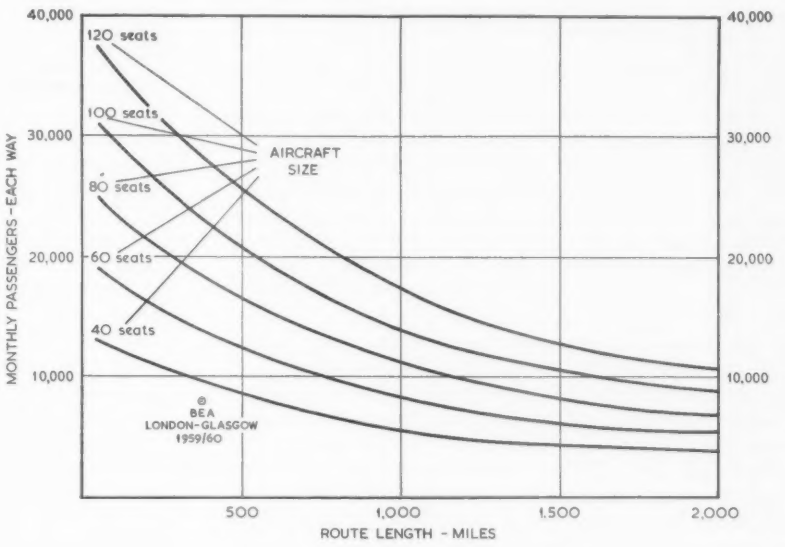

FIGURE 3. Traffic volume required to sustain competitive air services.

carriers will use. At any particular stage of air transport development the size of aircraft which will be used for different lengths of route can be regarded as more or less fixed: the range of choice of aircraft open to the airlines is sufficiently small that one can say approximately what size of aircraft will be used for any route under consideration. It is therefore possible to use the results plotted in Fig. 3 to give an answer, for example, to the question—"How much traffic would be required on the London-Glasgow route to support competitive air services?" At the present time, when competitive services are almost certain to be operated by Viscounts, the aircraft size we are concerned with is, let us say, 50 to 60 seats. At this size Fig. 3 suggests that the traffic required for competition is at about 12,000 passengers a month in each direction. In a year or two, however, competition is likely to centre around aircraft of at least the Vanguard's performance and no aircraft of less than 80 seats will be available which could be competitive. Hence the minimum traffic required for competition is likely to rise to at least 18,000 passengers per month in each direction. As a matter of interest I have shown on Fig. 3 the 1959/60 monthly average traffic carried by B.E.A. on the London-Glasgow route. I am concerned in this paper with the methodological approach to this question—not with particular cases—but you will observe that the London-Glasgow route, which is the U.K. domestic route with the highest traffic volume, does not appear to have enough traffic to justify competitive air services without the risk of incurring a higher level of operating costs.

But let me conclude this section by repeating something which I said at the beginning. I fully accept the assumption that there are circumstances in which airline competition, within an effective system of economic regulation, may provide a valuable stimulus to more efficient operations and to the provision of better service to the public. It is the responsibility of any licensing board to ensure that competition is encouraged only where and when it is likely to have these beneficial results.

LESSON 8
SPECIALISATION ON PARTICULAR KINDS OF OPERATIONS BRING GREAT ECONOMIC ADVANTAGES IN THE AIRLINE INDUSTRY

In the section before last (Lesson 6) I mentioned in passing that one of my recommendations in Canada was that some of the secondary routes then operated by T.C.A. should be taken over by regional airlines. On the face of it this recommendation may appear to conflict with the view which I have argued elsewhere[2] that, although there are no substantial economies of scale in airline operations after a certain size is reached, very small airlines are likely to have higher average costs than larger ones. This conclusion is, I think, demonstrably true of airlines engaged in the same kinds of operations: a small airline attempting to operate long-haul intercontinental services will inevitably have higher costs than a large one. But the situation we are now concerned with is rather different: we are comparing a large airline operating secondary services which are quite different in their nature from the main activities of that airline, with the possibility of a small airline undertaking those secondary services. My view is that the advantages of specialisation enjoyed by the small airline will outweigh the advantages of larger scale which the bigger airline may have. Indeed, the larger size of the major airline may be a positive disadvantage because of the difficulties of adjusting its operating and commercial practices to meet the special requirements of the secondary routes.

I recently saw a good example of the advantages which a small airline may have in dealing with specialised operations. British West Indian Airways has set up a subsidiary airline—Leeward Islands Air Transport—to operate with small aircraft a network of feeder services radiating from Antigua. L.I.A.T.'s scheduled services are operated with Herons and Bonanzas and a Piper Apache is also operated on charter work. Although the fare level on the routes operated by L.I.A.T. is fairly high, I think it is a remarkable achievement that this small airline has been able to operate this network profitably. Its financial success has been achieved, I think, by reason of three factors:

(*a*) a very tight managerial control has been exercised over all aspects of expenditure
(*b*) the overheads of the organisation have been kept to an absolute minimum
(*c*) a high work output has been obtained from an enthusiastic staff.

In summary, L.I.A.T. has taken full advantage of the

economies which can be achieved in a very small, highly personal and entirely specialised organisation.

The advantages of specialisation in airline operations go very deep and I would like to record here that I am quite sure that this is one of the major reasons for the success of B.E.A. in recent years. I am quite convinced that had we organised our nationalised airlines in one big Corporation in the post-war years, that airline would not have been able to develop the European and domestic market in the intensive way that B.E.A. has done.

The same sort of position exists in India where the Government followed the United Kingdom's example when it nationalised its airlines in 1953 and set up Air-India International for overseas services and Indian Airlines Corporation for internal services. You will recall that Mr. J. R. D. Tata, in his recent Commonwealth Lecture,[9] said that he fully supported this decision. In my own study in India I also reached this conclusion and the report of my Committee recorded the view that the merger of the two Corporations would make no contribution to solving the problems which faced I.A.C.[3] The Committee saw no reason why I.A.C., if it were able to find the solution to certain problems, should not soon eliminate the deficit incurred on its extensive internal network. I am glad to know that considerable progress has been made in this direction, for an efficient and economically operated system of air services is essential to rapidly expanding Indian economy.

I have already indicated that I see no case for merging B.E.A. and B.O.A.C. There may, on the contrary, be good reasons for the Corporations to consider establishing new subsidiary undertakings. I will give one example to illustrate what I have in mind. The services which B.E.A. operates to the Channel Islands are, in many respects, a specialised type of operation. To achieve maximum economy it is essential to develop operational practices, traffic handling methods, reservations and ticketing procedures which are different from those appropriate to B.E.A.'s mainline operations. It appears to me to be difficult to achieve the necessary degree of specialisation in dealing with these matters within the organisational framework of what has now become a very large airline. It is my personal view that B.E.A. ought, at some stage in the near future, to find some new organisational form—a semi-autonomous division or a subsidiary company—which would give the Channel Island routes the specialised management that is necessary for maximum economy in their operations.

Having devoted this section to the advantages of specialisation let me hasten to add that this does not imply that I favour a general move towards fractionalisation in the air transport industry. On the contrary, there are strong reasons for favouring more airline co-operation in many fields of activity and it is to these that I now wish to turn.

LESSON 9
VARIOUS FORMS OF AIRLINE CO-OPERATION ARE BECOMING INCREASINGLY DESIRABLE AND NECESSARY

I do not propose to go into much detail on this subject and in many ways this may be regarded as an economic lesson from long-haul operation rather more than from short-haul.

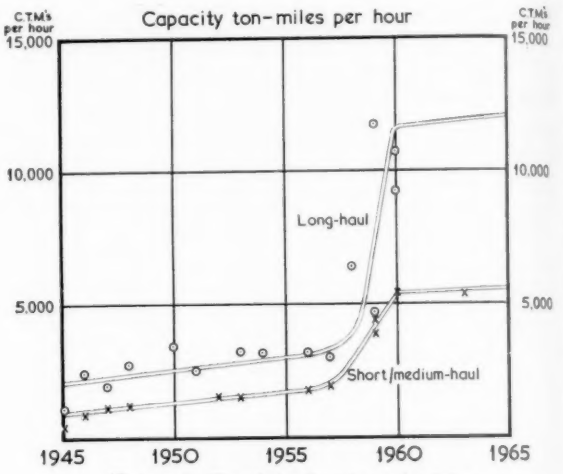

FIGURE 4. Trends in aircraft productivity.

The fact of the matter is that economic developments within the airline industry are creating new pressures towards closer co-operation between the airlines, particularly in technical matters. The most important reason behind this trend is the great increase in the productivity of the aeroplanes currently coming into airline service. The industry is going through a stage when average aircraft productivity—measured in C.T.M. per hour—is likely to increase by more than three times in a period of three or four years. This is illustrated in Fig. 4 which shows the trends for both long-haul and short/medium-haul aircraft. The current large increase in aircraft productivity is due both to the increases in size and in speed of the new generation of jet aircraft. It is useful to distinguish the problems which arise:

(*a*) from the speed increase
(*b*) from the size increase and
(*c*) from the combined effect of size and speed on aircraft productivity.

An increase in speed is almost always commercially attractive but a large increase can also create problems for the airlines. These occur in such matters as maintaining commercially desirable schedule times and in avoiding a fall in average aircraft utilisation. Airline co-operation can assist in various ways in overcoming the second of these problems.

The effects of an increase in aircraft size and an increase in aircraft productivity depend on the relationship between the growth in these factors and the increase in traffic volumes over the same period of time. It is because the percentage increases in size and productivity are substantially greater than probable traffic growth in the present air transport era, that difficulties are created for the airlines.

The growth in aircraft size is a factor which has created considerable pressure towards new pooling arrangements between the airlines, particularly in the long-haul field. And, if I may refer back for a moment to my earlier comments on the conditions in which airline

competition may be desirable, you will recall the importance which I attached to aircraft size in arriving at an answer to that question. It does strike me as somewhat perverse that Governments in this and other countries should have chosen the present time to adopt a policy of encouraging more competition when the economic facts of life are causing the airlines to move towards closer pooling arrangements to preserve adequate schedules with their much larger aircraft.

The fact that the percentage growth of aircraft productivity is greater than the increase in traffic means that the airlines collectively require a lesser number of aeroplanes to carry the larger traffic volume. For reasons which I discussed in some detail in another lecture[10] earlier this year, it is this economic characteristic of the present era which is obliging airlines to seek closer co-operation in the technical field. Broadly speaking this technical co-operation is taking two forms. On the one hand there are co-operative arrangements between airlines of more or less equal status, and in some of these cases the ultimate objective would appear to be a very close integration of all the operations of the airlines concerned. The co-operative arrangements between Scandinavian Airlines System and Swissair are, I think, the best example of this category. On the other hand there are arrangements by which small airlines co-operate with large airlines in order to get the technical advantages of the large scale facilities of the big brother. The arrangements between B.E.A. and Olympic are a good example of this kind of co-operation. The small airline is able, in this way, to maintain its individual identity in sectors of the industry in which it would otherwise become increasingly difficult for small airlines to survive.

There are all sorts of variations of the forms which airline co-operation is now taking and I have not attempted here to discuss the advantages and disadvantages of each system. I do think, however, that there is a clear lesson for all airlines that technical co-operation is extremely important in the present era and that each must seek the form which is most appropriate to its own special needs.

LESSON 10
SHORT-HAUL AIRLINE MANAGEMENTS MUST ALWAYS LOOK AFTER THE PENNIES

My final lesson from short-haul airline operations may seem rather obvious but I think it may be the most important of the ten that I have propounded in this paper. I said at the beginning that I rejected the idea that short-haul airline operations are inherently less economic than long-haul. The most important general conclusion that I have reached in studying short-haul operations in various parts of the world in recent years is that these networks are potentially profitable. But it is certainly true that the margin of profitability on short-haul operations is slender and is, I am afraid, likely to remain so.

It is this characteristic which makes it essential for the strictest managerial control to be exercised over all aspects of costs at all times in short-haul airline operations. This means that the airline must have the best possible system of budgetary control and efficient cost accounting methods to establish standard costs for budgeting.

But no system of cost control can be effective unless the staff of the airline are in full sympathy with its purpose. I will go so far as to say that no short-haul airline can be, and stay, profitable unless it has established an acute sense of cost consciousness at all levels of its organisation. And there is no shadow of doubt that this can only be achieved if this attitude of mind is imparted—and put into practice—at the topmost levels of management.

This is why I say that short-haul airline managements must always look after the pennies. Cost consciousness starts at the top—and without it the economic problems of short-haul airline operations would indeed be insoluble.

Conclusion

I have attempted to cover a lot of ground in this lecture but I wanted to try to synthesise the most important of the conclusions which I have developed over the past several years. I am conscious that one of the main dangers of this kind of lecture is that the conclusions are presented in a rather pontifical way. At those points where my conclusions appear most pontifical I have indicated the other places where I have elaborated on those subjects and where I have, I hope, given more adequate justification for those conclusions.

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DISCUSSION

Mr. Masefield (*Chairman*): They had heard a most fascinating lecture on a complicated subject which was of great interest and some of it was controversial. He thought this paper ought to be required reading for the new Air Transport Licencing Board before they tried to assess the difficult problems.

There were many points which he hoped would be raised in the discussion, such as Mr. Wheatcroft's views

on the supersonic transport's incursion into this type of business, the possibilities of the helicopter with its low speed problem and its high cost problem. He would also like to hear something from Mr. Wheatcroft on the segregation of individual route costs. He could not help wondering whether some of Mr. Wheatcroft's remarks about complete flexibility of passengers and freight were not slightly anti-Vanguard statements, whereas he personally believed that the Vanguard might turn out to be the right approach to the particular problem. Also, he was not sure that a pretty controversial debate could not be engendered on the subject of pooling or competition. There was an immense field for discussion in this excellent lecture.

K. G. Wilkinson (British European Airways. *Fellow*): He would like to take issue with the lecturer on two points. Firstly, Mr. Wheatcroft dismissed a little too glibly the question of the economic problems of short-haul operations; he was right to point out that the basic problem was the *high cost* of the short-haul operation of aircraft, but he thought there arose from this a number of consequences which in fact tended to make the economic problems of short-haul transport more difficult. This was primarily due to a simple fact: air travel had some advantages to offer over alternative forms of transport and whether the people flew depended on those advantages and on cost. As the length of haul came down the advantages offered by air got less and it became increasingly difficult to offer a time advantage. If, at the same time, the price of this air travel rose relatively to alternative transport they got a situation where in fact it was rather difficult to develop traffic, and therefore to get the high route density which Mr. Wheatcroft had so rightly pointed out as one of the basic requirements for economic travel. Thus, unless they had special circumstances, he thought one would be led to believe, from B.E.A.'s experience, that when one got down to a stage length of about 100 miles it was difficult to foresee a substantial air traffic developing at economic fares. Special circumstances, such as a water crossing, could modify this conclusion, but if there was no water crossing involved, 100 miles was a difficult length of haul on which to earn one's bread and butter. At 200 miles, there had proved to be advantages in air travel, although at first it seemed rather difficult to be certain about them, but London to Manchester and Manchester to the North had both proved successful air traffic sectors. At 400 miles they reached the length of haul where the advantages of going by air were sufficient to give them an undoubted place in the transport spectrum.

Secondly, he would like to comment that nowhere in these Ten Commandments had the lecturer mentioned as an important factor, the question of seasonal variation of the traffic flow and it seemed to him that was one of the fundamental factors. This seasonal variation traffic in fact could modify some of the lessons that had been enumerated, for example, lesson two on utilisation; ability to achieve high utilisation on a short haul was very dependent on this question of variation of traffic. Now, if, as on the Channel Islands, for example, they got something like a 16 to 1 variation between summer and winter traffic it was difficult to get adequate utilisation, particularly with modern equipment, whereas a route having approximately the same summer density but only a 2 to 1 variation, such as the Scottish routes (used as an example by the lecturer) presented a different set of economic problems but enabled high aircraft utilisation. The load factors that were aimed at would likewise depend on this seasonal traffic variation. Eighty per cent for the big aeroplane at high frequency might be sound for a route with little variation, but if they had to contend with something like 16 to 1 traffic variation there would be a problem in maintaining adequate winter frequency and a high load factor.

Choice of size of aircraft was likewise influenced by seasonality of traffic and the winter frequency problem, the resulting compromise again tending to raise operating costs compared with the steady traffic flow case.

Mr. Wheatcroft: He accepted Mr. Wilkinson's criticism that the lecture might give the impression of understating the difficulties inherent in short-haul operations. His feeling was that the problems of short-haul operations had been discussed so often and thoroughly in the past that the present need was for an emphasis of the inherent advantages which might be enjoyed by a short-haul airline if it fully exploited the market potential available to it. And he wanted to put very great emphasis on the economic advantages of high route traffic density, which could effectively offset the cost disadvantages of short-stage operations.

In talking about short-haul operations he had been thinking of routes down to about 200 miles and not the ultra-short routes of under 100 miles mentioned by Mr. Wilkinson. In this field of operations there was little doubt that the fixed-wing aeroplane had great difficulty in competing effectively with surface transport. This was precisely the reason why the helicopter, despite its inherently higher costs, became interesting for routes of this kind. But all that he had said about the economic importance of high route traffic density was just as relevant to helicopter operations as it was to fixed-wing operations.

He did mention the problem of seasonal traffic variation in his comments about the desirability for having flexibility in the disposal of aircraft payload and also in his comments about fares policies. He did not make it a main theme of the lecture because he did not think that short-haul operations were inherently more prone to seasonal variation than were long-haul routes. The degree of seasonal variation on the North Atlantic route was, as a matter of fact, greater than the average seasonal variation for traffic within Europe.

D. J. Lambert (Senior Designer (Civil Aircraft) Vickers-Armstrongs (Aircraft) Ltd., *Associate Fellow*): He thought it was an excellent and useful paper and work of reference; on the other hand they ought to note that Mr. Wheatcroft had used as his examples almost all the way through, areas of relatively low competition even though in some of them the flying was intense. Canada, as the basis of some of the discussion, had literally no competition worth commenting on and India was the same. The West Indies had been mentioned; that was a very low density operating area even though there was a variety of competition. He thought, looking at various points in this paper, that needed bearing in mind.

He deplored Mr. Wheatcroft's comments on high load factor. He thought the pursuit of high load factors was, to some extent, associated with the fact that he had just suffered a couple of very brutal lapses of service of airlines because of pooling. In both cases U.K. airlines were involved and in each case the opposite partner in the pool told him, "Oh, that's because Airline X won't agree to additional services even though we want to put them on." As a combined result he got back very late at night from a very long way away and suffered a ridiculously long wait of four hours for a connecting service to London at one of Europe's major cities to which he had been forced to go as a substitute for London. He thought it was quite clear that moderate, not high, load factors were the things the airlines ought to aim for and one of the most efficient airline operations in the world (and it had received a lot of acclaim and publicity for it) was that run by Continental in the U.S.A. who flew Boeing 707s in an intensely competitive area on an extremely low break-even load factor, at extremely low cost. They had a surprisingly low average stage length and achieved their low cost by smart turn round and intensive flying. He thought it was an important fact that the more intensive the flying the lower the costs for a given job; any aircraft left on the ground seemed to gather not only moss but man hours.

One thing that he thought was not mentioned adequately in the question of load factor was the provision

for the really big traffic peaks. Anywhere in the western world Friday night's traffic could pay a lot of wages on the airline and an airline with an *average* load factor of 80 per cent throughout the week obviously did not cope with the Friday night peak traffic or its customers particularly efficiently.

Mr. Wheatcroft just touched on the problem of whether the Vanguard was right or wrong as a concept. Obviously he could not give a direct answer, but it was interesting in Mr. Wheatcroft's paper to note that he concluded that it was the high passenger component in the payload of the high density Viscounts which seemed to be the thing that ensured them working economically. It was also interesting to note that on all the classically successful aeroplanes so far, the volume of freight capacity to passenger payload was surprisingly small. This was so in the DC-6B as it was in Viscounts.

Mr. Wheatcroft: He was quite unrepentant in his advocacy of the pursuit of a high load factor. The example which Mr. Lambert gave of profitable low load factor operations on Continental Air Lines did not move him. He fully supported—and had advocated in Lesson 2—the maximum reduction of costs by an intensive employment of aircraft and personnel. But surely Continental Air Lines would be able to charge lower fares, and thus expand more rapidly, if they operated at a higher load factor?

R. E. G. Davies (de Havilland Aircraft Ltd. *Associate*): He would suggest that while Continental made a good job of operating at low load factors, could they not make an even better job operating at high load factors?

Would Mr. Wheatcroft agree that nearly all the economy that had been derived from this theory of route density affecting economics was on the basis of such things as efficiency at stations, efficiency in reservations systems and so on, and did this not reopen once again the whole question on indirect costs.

It was suggested that if an airline had high density at short ranges this was as economic as low density at long ranges; he would suggest that this was almost invariably true, it was not a question of "if"; there were few airlines in the world that did not have a stage distribution curve which did not peak at the shorter stages. Would Mr. Wheatcroft like to give some advice to manufacturers as to which stage they should aim at for optimum productivity and economy in aircraft that they were building for short-haul?

Mr. Wheatcroft: He did not think that he could attempt to answer the last part of the question here but he would like to say a word about Mr. Davies' suggestion that all the economies of high route density were related to indirect costs. He did not think that this was entirely true. Many of the economies were in this direction. But they must not forget that major economies of high rate density arose from the use of larger aircraft and hence lower direct operating costs. Moreover, the achievement of a higher load factor, which was another outstanding important advantage arising from high route traffic density, could be regarded as a cost factor which had an equal influence on direct or indirect costs.

J. B. Scott (B.O.A.C.): Mr. Wilkinson had made some of his points, mainly on the utilisation question and effect of seasonal variation in load. But one point Mr. Wilkinson had not mentioned and Mr. Wheatcroft had also omitted, was the question of the directional variation seasonally. It might be that in the short-haul field there was no directional problem at all at any one time, but as Mr. Wheatcroft rightly pointed out in the beginning and as the Chairman had reminded them afterwards, what was now short-haul might also cover what they now thought of as long-haul operations. Certainly on the North Atlantic route, which would become a short-haul in the supersonic era, there would be seasonal problems directionally and they were going to have a tremendous effect, both on the utilisation of aircraft and more important, he thought, on the question of the load factor. In the example that Mr. Wheatcroft gave about load factors and achieving the optimum of 80 per cent there was no element for seasonal variations directionally over the route. On the Atlantic route that factor alone could bring the load factor down to probably 75 per cent and if one took that 75 per cent of Mr. Wheatcroft's 80 per cent one came down to 60-65 per cent load factor that was usually regarded as reasonable.

In regard to specialisation, where did Mr. Wheatcroft draw the line? What was a short-haul operation? Did he relate it to the stage length or to the ultimate origin and destination of the services? For example, were Middle East services long or short-haul?

Mr. Wheatcroft: He must agree with Mr. Scott that the directional flow of traffic was a factor which had a considerable bearing on the load factor which an airline could achieve, and he appreciated how important this problem was on the North Atlantic route.

His strong inclination was, however, to think in terms of solving seasonal and directional problems by tariff devices, hence his plea for flexible tariff policies. He felt fairly sure that something could be done about the directional problem on the Atlantic with new kinds of promotional fares. He suggested that the long-haul airlines had been much more reluctant than the short-haul airlines —particularly European—to experiment with special fares to overcome adverse variations in their traffic flows. The long-haul airlines had been much too concerned with the advantages of simplification in their fares and rates. It was interesting to note that the long-haul airlines which transit Europe were currently complaining that the European fare structure was too complicated and wanted to see it simplified. He hoped that the European airlines would vigorously defend the refinements which they had introduced to mitigate the problems caused by variations in their pattern of demand. These fare variations were tremendously important to the economic operation of European air services and, as he mentioned earlier, might largely explain how B.E.A. was able to achieve an average passenger load factor of 69 per cent in 1960.

Mr. Scott asked how far afield a short-haul airline had to fly before it became a long-haul operator. To his mind that question of specialisation turned very largely on the type of equipment used. There had been an overlap between B.E.A. and B.O.A.C. in the Middle East. But this did not alter the essential fact that the types of aircraft which the two Corporations needed for the bulk of their traffics were entirely different in their operating and economic characteristics.

A Speaker: Flexibility was obviously desirable but he would like to suggest a little soft pedalling on the idea of the "all-can-do" aeroplane which could do absolutely anything. Anything designed in that way could not be as good for a particular purpose as something designed for that purpose, obviously. He wondered whether everything was done that could be in the way of advertising and selling the things they had got, rather than trying to get something which they had not.

It seemed to him that the economics of all aeroplanes seemed to be worked out on at least as good a utilisation if not higher than had been achieved in the past and he wondered whether these could really be achieved in short-haul operations.

Mr. Wheatcroft: He would like to start to answer this question by making a comment on the Chairman's remark that some of the things said in the lecture might be interpreted as a criticism of the Vanguard. In one respect there was, he would admit, an element of criticism, although in general the Vanguard offered more flexibility than any other aircraft. The Vanguard's ability to carry a very large freight load without using the passenger cabin for this purpose was

a major advantage. But he thought that the extent to which the present total payload of the Vanguard exceeded the passenger-carrying payload would create some problems for the operators of this aeroplane. The problem would no doubt be minimised by putting as many seats as humanly tolerable into the aeroplane but a substantial excess payload was bound to remain.

He was quite sure that the short-haul airlines really did need an "all-can-do" aeroplane. And it must be designed to convert very rapidly from one rôle to another. Long-haul airlines were able to make conversion from one configuration to another during relatively long lay-overs at terminal points. But short-haul airlines must be able to make similar conversions in minutes not hours.

There had been very little evidence in air transport operations so far that utilisation rates tended to fall as cruising speeds increased. He agreed that if an airline were operating all routes of exactly the same length it would be more or less inevitable that increased speed would lead to a lower utilisation. But with a mixture of routes of different lengths the airline tended to get utilisation advantages as well as disadvantages in scheduling a faster aeroplane. He thought that this sort of "swings and roundabouts" situation was likely to continue even with the faster speeds of the next few years.

Mr. Masefield: They had had a most valuable lecture and beginnings of a discussion which he hoped would go on in other places and in print. There were many things he thought they would all like to have discussed further had time permitted. He would like to hear how Mr. Wheatcroft was getting on with the route cost allocations because that could alter the whole picture. The point raised by Mr. Scott about directional flow was a fascinating one which he thought Mr. Wheatcroft had dodged a little. One of the most heartening things to him had been the obvious success now of the London to Glasgow route; he remembered in the days when he was associated with B.E.A. the heartaches, worries, problems and arguments that there were on whether internal services in this country were worth operating at all. That the London-Glasgow route was a profitable and economic part of B.E.A.'s network was a great thing because this was a break-through in a new direction which could, he thought, in the long run, have an immense influence on the future of air transport in this country.

The President had asked him to apologise for his absence at the meeting; Dr. Moult had other tasks to do in the Branches but it had given him the opportunity of presiding over a lecture by his old friend, Steve Wheatcroft.

A. H. Stratford (Civil Aircraft Adviser, Sir W. G. Armstrong Whitworth Aircraft Ltd., *Associate Fellow*) *Contributed*: This lecture was of particular interest to all those working in air transport since it was rare to hear the economist's view on short-haul operations put forward in such detail. Perhaps Mr. Wheatcroft was the first economist to have been invited to lecture before the Society and it was to be hoped that the precedent would be followed. It was particularly significant at this stage since the requirements of the airlines had become an important consideration to the aircraft manufacturing industries in several countries who were eagerly wanting to understand the problems more clearly. They had thrown away the "hunch" and wanted to move beyond the simple cost formulae in determining specifications and the economic approach seemed to be necessary if they were to get to grips with the issues. It was noticeable, for example, in the paper that Mr. Wheatcroft concerned himself with the revenue earning aspects of the operation far more than with the cost aspects; even when considering utilisation he was concerned with aircraft productivity, the revenue creating side of utilisation, more than with the cost-affecting side of utilisation. This emphasis symbolised the different attitude of the operator and the designer. The aircraft manufacturer would be wise to mark and digest these principles.

The contribution of the aircraft designer in developing the latest techniques which would aid the operator in more economic operations could have been discussed more fully by Mr. Wheatcroft, for example the contribution that improved passenger and cargo handling equipment could make towards the overall economy on short-haul routes. A more original approach to passenger loading, perhaps by the use of pallets for passenger accommodation conversion to ensure quick turnround when converting between passenger and freight layouts could be more fully explored. Undoubtedly a greater flexibility in aircraft interiors, associated with the development of new materials to reduce wear and damage, was an aspect of aircraft design which could be more fully studied and was of particular significance to the short-haul operator.

In Mr. Wheatcroft's Lesson No. 3 he discussed the relationship between the frequency of service and the load factor, which few airlines seemed to have explored as fully as B.E.A. In recent studies of a supersonic air liner, for which high frequency of service and high rates of traffic growth were prerequisites for operating economy, few airlines seemed prepared to accept increased load factors above the 60 per cent level, although Mr. Wheatcroft had given a rational explanation of a principle which must surely be unchallenged.

When Mr. Wheatcroft discussed specialisation in his Lesson No. 8 one had hoped that he would mention the growing significance of air cargo. To follow up his line of thought special airlines, or special divisions of established airlines, might perhaps be suggested as the most efficient way of operating air cargo services. With special operating techniques and schedules which seemed to be necessary for air cargo, with different customers with a quite different attitude to the rate they paid, and with specialised aircraft now available to achieve maximum revenue in relation to cost, surely they had the most significant specialisation of short-haul air cargo in their time. It was widely accepted now that in short-haul operations air cargo had its greatest future. There might be the eleventh lesson which was now at last being learnt.

Mr. Wheatcroft: He was glad that Mr. Stratford, as a representative of the manufacturing side of the industry, fully supported what he had said about the need for flexibility and a design criterion for short-haul aeroplanes. He thought that the particular suggestions Mr. Stratford made for improving the flexibility of such aircraft were interesting and hoped that they would be pursued.

He must apologise for having said so little about air cargo. He certainly agreed that the short-haul air cargo market had better prospects for immediate large scale exploitation than the long-haul. But he was still not sure whether any all-cargo aircraft held immediate prospect of self-sufficient operations in the short-haul field. He suspected that the large freight capacity which would shortly be available in passenger aircraft might cause rates to be reduced below the level at which current all-cargo aircraft could operate profitably.

P. W. Brooks (British European Airways, *Associate Fellow*) *Contributed*: Mr. Wheatcroft implied, in replying to the discussion, that he was not entirely serious in his attempt to "de-bunk" that accepted tenet of airline economics that long hauls were more economic than short. As a generalisation, "the shorter the haul the peakier the business" (anybody who used London Transport saw this demonstrated every day) and seasonal and directional fluctuations in traffic were the most serious economic problem of short-haul airlines (and of B.E.A. in particular). He agreed with Mr. Wilkinson that this factor more than offset in practice the economies which resulted from higher traffic densities.

At the same time, Mr. Wheatcroft's conclusions in the West Indies could also be understood. For small airlines, long-haul operations today were both difficult and costly.

Small airlines could do an entirely adequate job, and even make money, in regional operations over a short-stage network, but it was another thing altogether to try to run even the smallest fleet of long-haul "big jets" with only a small organisation.

In his Lesson 4, Mr. Wheatcroft showed the benefits which could result from closing the gap between passenger and overall load factors and cited B.E.A.'s policy in recent years as an example. However, this was really only a less obvious way of pointing out that B.E.A. had succeeded during this time in more closely matching the payload/range characteristics of its aircraft to the route network and this was surely an even more important lesson. The increased payload in the later Viscounts reduced both their optimum range and their specific operating costs. On the majority of B.E.A.'s stages, this gave a most significant improvement in operating economy.

Mr. Wheatcroft made an important point about the need for flexibility both as between freight and passenger accommodation and between classes in mixed-class aircraft. Flexibility between classes could be particularly valuable because the two classes could then share the booking cushion which was discussed in Lesson 3. Only by such flexibility could they avoid the serious decline in load factor which was otherwise inevitable with mixed-class aircraft.

He disagreed with Mr. Wheatcroft's arguments against cross-subsidisation of short-hauls by long-haul profits. In his view, such cross-subsidisation had made a most important contribution to the development of air transport and would continue to do so. The lecture was, in fact, contradictory in that it cited B.E.A.'s development of the domestic trunk routes as one of its more creditable achievements and yet, at the same time, attacked the very method by which this had been achieved. It was only by cross-subsidisation of the originally highly unprofitable domestic trunk routes by means of the profits made on the international services that B.E.A. was able to pursue the low fare policy and the generally aggressively expansionist programme on these routes which had led to their development to a profitable state.

The fact was that, *provided there was an overall economic benefit in the long-term,* there was as good a case for cross-subsidisation between routes as there was for it between flights on any particular route—the latter policy being quite rightly strongly advocated by Mr. Wheatcroft. (Lesson 5). While he agreed with the lecturer that, in the case of social services the airline should normally be given government assistance and should not depend on cross-subsidisation, he also believed that the most rapid development of air transport as a whole would result from a policy of the lowest possible fares on those shorter routes which appealed to the largest numbers of passengers—and, moreover, to those passengers who were most sensitive to price. The longer hauls would always appeal to the far fewer people and to people who tended to be less fussy about what they paid. They were also, as Mr. Wilkinson pointed out, getting far better value for money than the aeroplane passenger on short hauls who wasted so much time on the non-flying parts of his journey. In the circumstances, a policy of maintaining high revex ratios* on the longer hauls and considerably lower ones on the short hauls of greatest traffic potential seemed to him to be entirely defensible as a long term policy and not one justified only during the early stages of the opening up of a new route when losses—and cross-subsidisation—were normally accepted as a development expenditure.

They had to remember that the shortest hauls were air transport's most important "show window." At a time when less than four per cent of the population used the air, it was vital that the airlines concentrate on attracting new customers. Many of the honeymoon couples to the Channel Islands and the "first-flighters" to Paris, which B.E.A. had carried during the past 14 years, had subsequently become frequent air travellers. But for that first inexpensive flight on a short stage, they might have remained with the 96 per cent of people who had never been near an air liner.

In Lesson 8, Mr. Wheatcroft suggested that B.E.A. should "hive-off" its Channel Islands operations in order to achieve that specialised management which was necessary for maximum economy. As the lecturer was well aware, the problem of how best to handle the Channel Islands routes had long been a subject of study and controversy within B.E.A. The fact was, however, that nobody had yet been able to show any likely economic benefit from a change in organisation so long as those routes were operated with equipment which was also used elsewhere on B.E.A.'s network. The advantages of integration were too great. The case for an autonomous subsidiary was unlikely to be proved until the Channel Islands routes could be economically delegated to an independent operating unit using aircraft and crews which had no important applications elsewhere.

Mr. Wheatcroft was perhaps less than fair to governments in Lesson 9 when he said—and he, for one, agreed with him—that it was somewhat perverse of them to start encouraging competition just at a time when economic factors, resulting mainly from the introduction of the large new jet aircraft, were forcing the airlines into closer pooling agreements. Mr. Wheatcroft, himself, did after all make recommendations in favour of trans-continental competition to the Canadian Government only two years ago.

Mr. Wheatcroft: He had already said in reply to Mr. Wilkinson that he could see no reason for believing that short-haul services were inherently more peaky than long-haul. This did not mean that he denied that seasonal variation had been a major problem for short-haul operators in Europe. He wrote about these problems at length in "The Economics of European Air Transport."

Perhaps Mr. Brooks and he were at odds only about terminology on the subject of cross-subsidisation. He entirely agreed that it was desirable for an airline to incur developmental losses on routes which held promise of future commercial success. He regarded this in the light of being a good investment. His objections to cross-subsidisation arose where the routes in question showed no prospect of becoming profitable and also to circumstances where the burden of unprofitable routes made the airline unduly dependent upon the high profits earned on others.

He did not quite understand Mr. Brooks's final comment. The remark about the perverseness of trying to introduce competition at the present stage of air transport development was, in fact, a paraphrase of a statement made in his report to the Canadian Government.

*Mr. Wheatcroft's suggested term for "operating ratio" which he agreed was more self-explanatory.

Historical Group

My First Ten Years in Aviation

BY

SIR THOMAS SOPWITH, C.B.E., Hon.F.R.Ae.S.

(Chairman, Hawker Siddeley Group)

The first lecture to be given before the Historical Group of the Society—" My First Ten Years in Aviation," by Sir Thomas Sopwith, was given before a large and distinguished audience on 21st November 1960 at the Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1.

The President of the Society, Dr. E. S. Moult, C.B.E., B.Sc., F.R.Ae.S., M.I.Mech.E., opening the proceedings, said that although the By-Laws of the Society stated that if the President were at a meeting he must take the Chair, he proposed handing over to Mr. Peter Masefield, Immediate Past President, because the suggestion for this lecture had come in Mr. Masefield's term of office and he thought Mr. Masefield should preside.

Mr. Masefield: This was a great occasion for the Royal Aeronautical Society because it was the first meeting and the first lecture of the new Historical Group. To have Sir Thomas talk to them for this inaugural lecture and to see such a galaxy of aeronautical talent present was a great pleasure. In particular, he was delighted to have Lady Sopwith with them and, to mention just a few others, Sir Geoffrey de Havilland, whom they saw all too rarely these days, Sir Roy Dobson, Sir Sydney Camm—in fact many of those who had borne the burden of the day in British Aviation. There were two others he would particularly like to mention: Dr. Peter Thurston, one of the oldest members of the Society, who had worked with Maxim way back in those very early days of flying; and they were also delighted to welcome Laurence Pritchard, former Secretary.

The Society prided itself on keeping in the forefront of progress and, two or three years ago, had formed an Astronautics and Guided Flight Section, peering ahead into the future. But, to balance things, they had felt recently that they should have an Historical Group. The Group was formed to encourage the study of all historical aspects of aviation and to try to act as a spearhead, with other bodies, in preserving matters of major aeronautical historical importance. One of the things the Group had done already was to draw up a register of all historic British aircraft and aero engines known to exist, not only in this country but elsewhere, and after the lecture he would ask Dr. Moult to present to Sir Thomas the first of the plaques which were to be put on all British Historic aircraft to record their name, where they were built, and the fact that they were of historic importance. He hoped this would prevent their disappearance in the generations ahead.

There were four sides of the business that they hoped to concentrate on in the Historical Group: the preservation of aircraft and engines, including the register of British Historical Aircraft; records of historic importance, everything from drawings and blueprints to historic films and photographs; the library side, the books and the prints; and finally, and perhaps the most important of all, lectures on the background history, results of research and, perhaps most of all, " the pioneers on their pioneering." A series "My First Ten Years" by different pioneers in the next session would be of unique interest. How wonderful it would be today if they had the Wright Brothers or A. V. Roe talking of their early days and had them recorded, as this evening they were recording Sir Thomas Sopwith. In generations to come what Sir Thomas was going to tell them would be on record for people to hear in his own voice.

As he had said, to have Sir Thomas Sopwith to give this inaugural lecture was a very great pleasure. He was truly a pioneer. The Sopwith name had become famous in the Royal Flying Corps and in the Royal Naval Air Service during the First World War. Sir Thomas still had his youthful enthusiasm as in the days of the Tabloid, the Pup, the Camel, and the Snipe, and his great efforts in the Americas Cup, all those things which filled so many books and were so much a record of the historic past. His was a full life and a great life. He held the Royal Aero Club's Aviation Certificate No. 31 issued in 1910; he founded Sopwith Aviation Co. in 1912 at Kingston-on-Thames, which was well known today under the Hawker flag; he built there many famous types of aeroplane and he was still Chairman of the Hawker Siddeley Group; he received the C.B.E. in 1918 and his knighthood in 1953 and there could be no one more fitting to give the first lecture of the Historical Group of the Royal Aeronautical Society.

MY first illustration Fig. 1 shows how the World's very first powered flight was announced in this Country—and it had no more notice in any other—I cannot help feeling that the first manned space flight will cause a slightly greater fuss.

I suppose it really all began, so far as *my* urge to fly was concerned, in the summer of 1910. At that time I owned half a 166 ton schooner—the owner of the other half was my old friend Bill Eyre.

Incidentally, the engineer in charge of the auxiliary engine was Fred Sigrist. We were to remain in partnership through many varied experiences in aviation for the following 30 years.

We had left Le Havre and as we were becalmed in the Channel we put into Dover Harbour. There we heard that an American architect of Spanish descent, Johnny Moisant, was flying a Blériot monoplane (Fig. 2) in a field nearby so we thought we would go and have a look.

(Moisant or Moissant? The name is spelt with one

now small, and it will certainly be lost next year, when further Russian reinforcements arrive.

BALLOONLESS AIRSHIP.

(From Our Own Correspondent.)

NEW YORK, Friday, Dec. 18.

Messrs. Wilbur and Orville Wright, of Ohio, yesterday successfully experimented with a flying machine at Kittyhawk, North Carolina. The machine has no balloon attachment, and derives its force from propellers worked by a small engine.

In the face of a wind blowing twenty-one miles an hour the machine flew three miles at the rate of eight miles an hour, and descended at a point selected in advance. The idea of the box-kite was used in the construction of the airship.

LEGACY OF THREE MILLIONS.

(From Our Own Correspondent.)

VIENNA, Wednesday, Dec. 16.

Lieutenant Barth, an officer belonging to a Hungarian regiment of Hussars stationed at Debreczen, has received his commission,

FIGURE 1. From the *Daily Mail*, 19th December 1903.

"s" in the Aero Club de France list of Aviators' Certificates. In 1910 the Press spelt it both ways. Geoffrey Dorman recalls how, when an inquisitive teenage lad, he asked the pilot for his autograph to find out how the name should be spelled and the pilot wrote it "Moissant" when he landed at Beckenham. So Dorman queried "Is that the proper way to spell it?" and the pilot retorted "That's how *I* spell it son"—which makes confusion worse confounded. Maybe the pilot spelt it with two letters "s" for personal reasons. Lord Carbery when he adopted American citizenship to shed his title called himself John Carberry.)

Aeroplanes were rare birds in those days, for it was barely a year since Blériot had flown the Channel.

Moisant's flying started something inside me. I was incurably bitten by the aviation bug then and there and never recovered. I decided I must fly too.

Incidentally, Johnny Moisant was then making a niche in aviation history for himself by making the first flight between Paris and London and was the first to cross the Channel with a passenger—a hefty mechanic named Albert Filieux. Now that a man has got from the Marble Arch to the Arc de Triomphe in just over 40 minutes it is interesting to recall that Johnny Moisant took 22 days to fly from Issy, (first a military parade ground and then an aerodrome and now the Paris heliport), to a cricket field on the outskirts of London. All went well at first and he reached England on the second day of the flight and landed about seven miles from Dover. And there his troubles began for the wind rose bringing heavy rain. Remember he had but a 50 h.p. Gnôme engine which did not develop much more than 35 h.p. and Moisant and Filieux averaged about twelve stone.

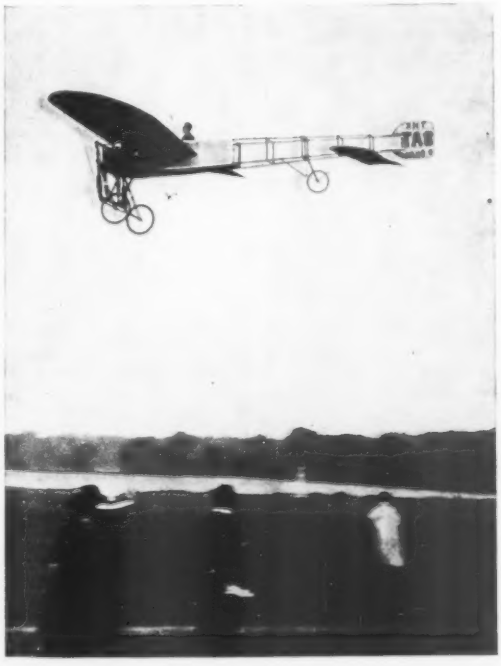

FIGURE 2. A Blériot monoplane, 1910.

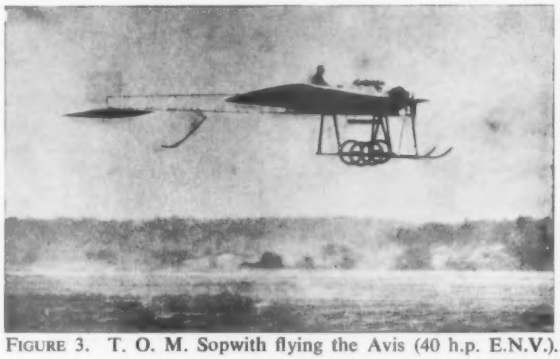

FIGURE 3. T. O. M. Sopwith flying the Avis (40 h.p. E.N.V.).

They persevered, however, and the undercart was damaged more than once; they broke an airscrew and had to wait for another to come from Paris by train and ship. They had intended to land in the Crystal Palace grounds where Claude Grahame-White had been giving exhibitions in a Farman, but Moisant did not like the look of it so he turned back and landed on a cricket ground at New Beckenham. Someone who was on the spot soon after remembers Moisant and Filieux looking tired but happy; they had achieved their goal. The propeller and undercart were damaged again and so was the cricket pitch. And the cricketers whose game they interrupted were looking black and muttering something about "These damned foreigners. What else can you expect?" little knowing they had seen history made! Alas, Johnny Moisant was killed on the last day of 1910 preparing for an attempt on the American Michelin Trophy for the longest non-stop flight by the end of the year.

From Dover I repaired to Brooklands where Mrs. Maurice Hewlett was selling flights at a fiver a time in a Henri Farman flown by the Frenchman Gustav Blondeau. I paid my fiver and was taken for a sedate cruise consisting of two circuits of Brooklands.

Mrs. Hewlett made history a little later by teaching her son to fly.

Well,—once I had been in an aeroplane I simply had to fly myself. I had done a lot of ballooning in the previous couple of years in a balloon built for me by the Short brothers who were then official balloon makers to the Aero Club—before it became the *Royal* Aero Club. I had also made several ascents with Charlie Rolls and Frank Hedges Butler, who between them founded the Aero Club.

But I wanted to fly properly, so I bought a little Avis monoplane with a 40 h.p. E.N.V., designed by W. O. Manning and built by Howard Wright (Fig. 3). Perhaps I should explain that Howard Wright and his brother Warwick were well known motor car engineers and no relation of Wilbur and Orville. This Avis had no dual control—it had not been thought of then—so I just got into the thing and taught myself, taxying first or "rolling" as we called it. A new vehicle had just come on the London streets which the bone-headed bureaucrats of the day designated the taximeter-motor cabriolet, soon dubbed taxi by the public. So we at Brooklands adopted the word for our own use on the initiative of that great

FIGURE 4. T. O. M. Sopwith in the Howard Wright biplane (60 h.p. E.N.V.).

pilot and character D. G. Gilmour—or so C. G. Grey always said, and C.G.G. wrote pretty accurate stuff about the early days of flying. Anyway the word is now part of the international language of aviation.

In the course of my self training I had an almighty crash in the monoplane resulting from a stall but did not hurt myself. I could not stop now so bought a much larger Howard Wright biplane, with 60 h.p. E.N.V. and Fig. 4 shows me in it. Notice how unprotected the pilot was from wind and weather.

When I got the hang of rolling I tried straight flights and then circuits. That day Harold Perrin turned up to observe Clement Greswell (who is still alive at 83, living at Cooden Beach) for his Aviator's Certificate. Later he became one of Claude Grahame-White's star pilots. When he completed his tests Perrin suggested that I should have a go to save him coming down again especially. So I did and was awarded ticket No. 31 on 22nd November, 1910. On the afternoon of the same day I took up my first passenger, W. O. Manning, who had designed the biplane—just to "larn" him!

Claude Grahame-White made his gallant attempt on the London to Manchester flight in April 1910—just over half a century ago. In the course of this struggle he started his second day's flight in the pitch dark—this was probably the first night flight in history. Grahame-White had a flying school at Brooklands before establishing Hendon. But when I began flying he was in the United States where he won the Gordon Bennet Challenge Cup for Britain, the first international air speed race. Claude made a highly successful tour in the States and when invited to the White House to meet President Taft he landed his Farman in the street in Washington outside the White House. There were fewer frustrations in those days and you could do that sort of thing.

And that reminds me. The Royal Aero Club was then on the third floor of 166, Piccadilly opposite the end of Bond Street. I once bet several friends a fiver each I would lie on my back in Piccadilly for five minutes without being moved by the police or anyone else. I won my bet. For then cars could be parked down the centre of Piccadilly, so I lay under mine for the five minutes.

Well, as you can imagine my first efforts at flying, including crashing the monoplane and buying the biplane, cost me quite a bit, so I decided to try and get some of it back by having a go for the big prizes. There were two, I thought, that were on the list of possibles. The first was the Michelin for the longest non-stop flight by a British pilot in a British aircraft. The other was £4,000 offered by Baron de Forest for the longest non-stop flight from any point in England to anywhere on the Continent.

Baron de Forest, now Count de Bendern living at Biarritz aged 81, was resident in England during the early part of the Century and was an M.P. He became interested in flying after seeing Henri Farman's early efforts in 1907. When Blériot flew the Strait of Dover in 1909 this event struck the Baron as one of tremendous strategic importance to Britain. So to stimulate British aviation, then practically non-existent, he offered his prize (substantial in those days) for this ambitious flight in an aeroplane wholely manufactured in the U.K. Its object was undoubtedly attained, leading as it did to the eventual formation of the Hawker Siddeley Group.

Almost at the end of November I had a go at the Michelin in the Howard Wright biplane and covered 107 miles in 3 hours 12 minutes, a British distance and duration record. Cody, however, was making determined efforts to win the Michelin and as I could not make a proper job of both I decided to leave the Michelin to him and go for the de Forest prize instead. Both closed on the last day of 1910, so time was short.

Fred Sigrist had a theory that the most likely time for an engine to fail was in the first few minutes of full throttle, so he advised me to start on the flight to the Continent from Eastchurch, which meant about half an hour's flying over land before the Channel. We took the Howard Wright by road from Brooklands to Eastchurch and a few days before Christmas there was a dead calm and I took off at 8.30 on the morning of 18th December. I had hoped to reach the Chalons-Rheims area. I passed over Canterbury at 1,000 feet, this was my altitude record so far, and with a following wind was over Dover in half an hour. I remember feeling very alone and so to relieve the constant apprehension of a change in engine note I started to sing—this, my wife insists, is *not* one of my outstanding talents, but the odd carol, tuneful or not, served well.

Twenty-two minutes later I crossed the French coast, exactly where I have never discovered to this day, but I was very relieved to see it. My compass persisted in pointing N.W. no matter how I turned; so I steered by the sun but soon it was hidden by cloud so I continued to fly straight ahead as best I could, passing south of Lille where it was bumpy. Soon I crossed the Belgian frontier and it got so rough I was nearly thrown out, but hung on with one hand under the seat. We had no seat-belts in those days; nor did we have such luxuries as an air speed indicator. The only instruments were a rev counter which worked, a compass which did not and a barograph—a very sensitive one which Cecil Grace had given me, 6 in. in diameter and reading to only 2,000 ft.

The wind was rising and hilly country lay ahead, so I decided to land at the first favourable spot, a field near Beaumont. I was getting frightened! I still had 11 gallons left from the 20 with which I started, so if the weather had been better I could have covered over 300 miles. However, the distance in a straight line from East-

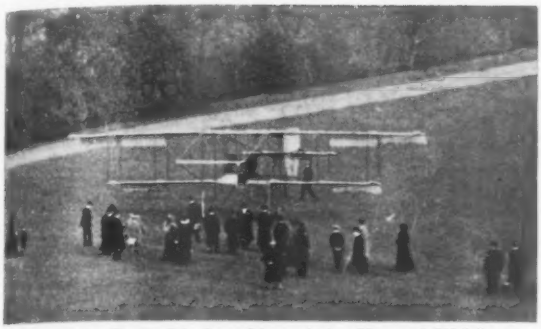

FIGURE 5. T. O. M. Sopwith and the Howard Wright at Windsor, 1911.

church was 169 miles and as the weather got worse no one else beat me and I was awarded the prize when the competition closed on 31st December.

Luck played its part, for I was a mere tyro with less than two months flying experience and my rivals included Claude Grahame-White, Robert Loraine, Cody, Frank McClean, Clement Gresswell and Cecil Grace. Cody was concentrating on the Michelin and hoped to have a crack at the de Forest prize starting from Farnborough. But very soon after my flight the weather clamped down; wind rose to gale force and wrecked the hangars at Dover where several competitors housed their aircraft.

On the day of my flight, but not till after mid-day, Cecil Grace started from Eastchurch in a Short box kite, but the rising wind and low cloud forced him to land at Dover; four days later, 22nd December, he had another go and landed near Calais as the wind was so strong that there was no chance of beating my distance, so he started back for Dover to have another try, but ran into fog, missed the Kent coast and was never seen again. He must have flown on over the North Sea until his petrol was exhausted, for he was heard by the crew of the North Goodwin light-ship and a Ramsgate coastguard. He was the second British pilot to lose his life flying, the first being Charlie Rolls at the Bournemouth meeting that summer.

Cody eventually won the Michelin with a flight of 185 miles in 4 hours 47 minutes, setting up new British distance and duration records. Alec Ogilvie in a Baby-Wright with NEC engine came second with 140 miles. He is still alive and well. He was a keen pilot in the early days.

Early in 1911 I received an invitation from King George V to fly to Windsor—it was not exactly a command because the King knew full well the uncertainties of aviation then. So on 1st February I left Brooklands in quite a fog, having discovered it was clear at Windsor. On the way I landed on Datchet Golf Course to patch up a leaking radiator and then circled Windsor Castle and landed below the East Terrace, and there we are (Fig. 5). Customary protocol was put in reverse, as the King was waiting for me and led two small boys by the hand to examine the Howard Wright. The two princes were Prince Henry and Prince George.

FIGURE 6. A Martinsyde Monoplane, 1911.

That cheerful and colourful character, Douglas Graham Gilmour, a Scot, who as I have already said was largely responsible for the word "taxi" in flying, and one of our foremost pilots, was sometimes in trouble for rather naughty flying. In 1911 he made history—and officialdom angry—when he flew over the Oxford and Cambridge boat-race in a Bristol Boxkite. There was quite a lot of open country in those days along the boat-race course and plenty of fields where he could have landed all right.

Later that year when he flew low over crowds at Henley Regatta his Certificate was suspended by the Aero Club, so he could not fly in the Circuit of Britain. Later that year he was killed in a Martinsyde monoplane (Fig. 6) when the wings collapsed over Richmond Park. I had often flown that machine and flew it only just before the fatal flight.

Although 1910 is now regarded as the "golden year" of flight in Britain, it was in 1911 that it really got going properly. In April that year Pierre Prier, Blériot's chief instructor at Hendon, startled the world by flying non-stop from London to Paris in four minutes under four hours. The fastest by train and ship was seven hours. He flew a 50 h.p. Gnôme Blériot from Hendon to Issy and his time of 3 hours 56 minutes was a vast improvement on Johnny Moisant's 22 days. We were on the way to 40 minutes—but still had a long way to go.

Claude Grahame-White won the Gordon Bennet in America in 1910, so the race was held in England at Eastchurch in 1911 and it was won by the American Charlie Weyman in a French Nieuport. Britain was represented by Gustav Hamel in a Blériot and Alec Ogilvie in his Baby-Wright. In order to match Weyman's speed Gustav cut great chunks off the wings of his Blériot and it looked a terrifying spectacle. There was never much lateral control with the warping wings of a Blériot and in Gustav's clipped-wing racer there was virtually none. He was unable to recover after banking steeply round the first pylon and crashed. Luckily he was thrown clear and escaped with cuts and bruises.

That year also saw three great international races, Paris to Madrid, the Circuit of Europe and the Circuit of Britain, a one thousand mile race round England and Scotland starting and finishing at Brooklands. I did not take part in any of these, as I was flying in the United States. It is now history how the French naval pilot, Lieut. de Conneau, flying under the name of André Beaumont, started hot favourite after sweeping to victory in the continental races in an epic struggle with Jules Vedrines (who had been Bob Loraine's mechanic). In spite of their lesser experience in air racing British pilots did not do so badly, for Jimmy Valentine in a French Deperdussin came third and Cody was fourth.

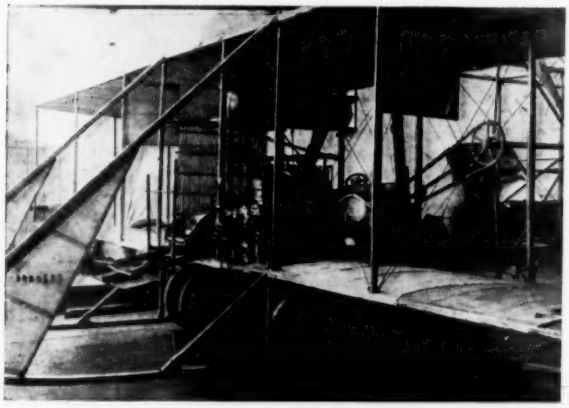

FIGURE 7. Burgess Wright Biplane (40 h.p. A.B.C. motor, chain drive), 1911.

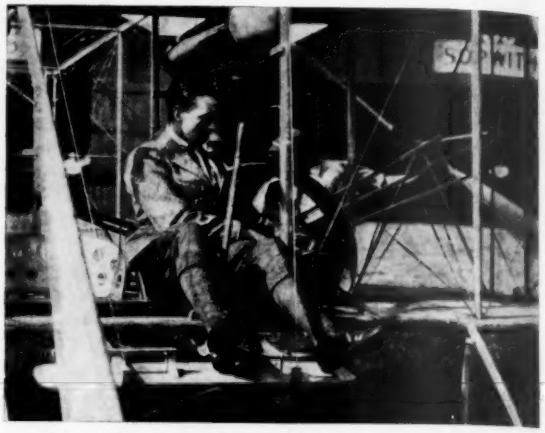

FIGURE 8. T. O. M. Sopwith in the Burgess Wright.

Indeed these were the only four to finish the course out of a field of 17.

That summer I went to the United States and after his great success there in 1910 Claude Grahame-White decided to go again too. Between us we cleaned up a lot of prize money at the three main meetings at Chicago, Boston and New York. I was accompanied by Fred Sigrist as engineer, and Claude by Reggie Carr in a similar capacity. Carr still works in aviation with Handley Page.

Soon after arriving in America I was flying the 70 h.p. Blériot with Nelson Doubleday the publisher as passenger and spun into the ground—we were not seriously hurt and, of course, did not know then that it was a spin. He told me later that this was his fourth crash in five flights.

One event I specially remember was a quick-starting competition when pilots had to run to their aircraft, start the engine and get cracking and the winner was the one who was airborne quickest. My time was 9 seconds so you see there is nothing really new in these "new fangled" S.T.O.L. aircraft. I did this on an American Wright biplane I bought in the States. I also took my 70 h.p. Gnôme-Blériot to fly in speed events. Claude had a fast Nieuport monoplane like the one Weyman won the Gordon Bennet Race with and he cleaned up several races with it.

Altogether I was lucky enough to win a lot of money in the United States. And with the £4,000 de Forest prize in the bank I began thinking of forming a company of my own. It is difficult to put an exact date to the start of the Sopwith Aviation Company—like Topsy "it just growed".

But it was the tiny seed that was to grow into the Hawker Siddeley Group of to-day.

We began in a small way with a flying school at Brooklands with a Burgess-Wright (Fig. 7) a variant of Wilbur and Orville's biplane, for dual instruction. That is me in it (Fig. 8). There was also the Howard Wright biplane and the 70 h.p. Gnôme Blériot for more advanced flying. Freddy Raynham, who died in the United States six years ago, joined me as instructor in the early part of 1912.

I often flew in pylon and cross-country races held at Brooklands at weekends, mostly in the Blériot and sometimes the Burgess-Wright, now and then popping across the 20 miles to Hendon to race there.

In June 1912 I was one of thirteen entrants for the first Aerial Derby, an 81 mile circuit of Greater London starting and finishing at Hendon.

The first prize was a gold cup presented by the *Daily Mail*. I flew my 70 h.p. Gnôme Blériot and Gustav Hamel flew a 50 h.p. Gnôme Blériot with the owner, Miss Trehawke Davies, as passenger. Other pilots well-known at the time included Benny Hucks on a 50 h.p. Gnôme Blériot and the Frenchman Maurice Guillaux in a Caudron monoplane which incidentally was the fastest machine in the race. There was Billy Moorhouse (later Rhodes-Moorhouse and the R.F.C.'s first V.C.) in a monoplane he designed with Jimmy Radley with a 50 h.p. Gnôme, John Porte in an Anzani-engined Deperdussin, Sidney Sippe (who I am glad to see here tonight, looking half his age) in a 50 h.p. Gnôme Hanriot monoplane, Jimmy Valentine in a Gnôme-Bristol monoplane and Verrier in a 70 h.p. Renault-engined Maurice Farman which the R.F.C. called the Longhorn.

I was the first to finish, but was told I was disqualified as I had not been seen from the Purley control, so it was assumed I had turned *inside* it. I was quite sure I had not gone inside, as I made a rather wide turn there. Soon after I landed Guillaux in the Caudron monoplane was seen approaching, but he had the bad luck to run out of petrol within sight of his goal. Gustav Hamel landed second and as I was disqualified he was declared winner. Billy Moorhouse was the third to land and then came Jimmy Valentine. My time was 1 hour 23 minutes and Gustav, with the lower power and a passenger, clocked 1 hour 38 minutes.

I lodged a protest against my disqualification and had a side bet with Gustav that whoever was declared winner would stand a dinner to the rest of the competitors. After a week the Stewards decided they could not uphold my protest, so I appealed to the Stewards of the Aero Club who thought about it for five whole months and finally upheld the protest because the observers had been badly sited to see, but other witnesses had seen me pass

outside the turning point. So all was well and I stood the dinner and got a magnificent gold cup.

The dinner was duly held at the Café Royal and it must have been a success as Cody, all dressed up, went to sleep in the train taking him back to Farnborough and woke up in Bournemouth.

They were a wonderful crowd of personalities at Brooklands at this time. No one could ever forget that brilliant pilot and humourist with a stutter, Gordon Bell; there was Warren Merriam of the Bristol school; Smith Barry, a pupil on my Burgess Wright, who was later to devise a method of teaching the world to fly. Eardley Billing (Pemberton Billing's brother) and his wife who ran the famous Bluebird café for us. Jack Alcock who, after being a mechanic with a firm in Manchester, joined Ducrocq to fly a Maurice Farman with Sunbeam engine. There was George Handasyde (who died recently at a great age) who designed the magnificent Martinsyde; Henry Petre who is one of the oldest pilots "still in captivity," Geoffrey de Havilland whom I am happy to see here. Rex Pierson, who designed the Vimy in which Jack Alcock flew the Atlantic, learned to fly at the Vickers school and was to succeed Harold Barnwell as Vickers' Chief Designer when Barnwell was killed. His brother Frank Barnwell of Bristol was also killed flying some years later.

There was Keith Davies, the first man to fly in India and still very much alive; Henry Sabelli, N.S. Percival, called Streamline Percy as he was so thin, who died in December 1959; the hunchback designer, Howard Flanders, and his famous monoplane; and Fisher who flew it and was killed in a sideslip in 1912. Then I remember Flemming and Pizey the Bristol instructors, Flemming tall and Pizey short. And Howard Pixton, of whom more later; Otto Astley and "Daddy" Sassoon, now Sir Victor, who were joint owners of a two-seater Blériot. "Daddy", who was a bit short-sighted, was flying this machine one day and made a beautiful landing—but about 20 feet up in the air with the inevitable result of a nice crash. It took several weeks to repair and the next time he flew Otto said to him "Now Daddy fly the bloody thing right into the ground before you flatten out". And he did! Another pile up, but no personal damage.

And about this time four young Australians came to England to study flying—two came to me and the other two went to Bristol's. They were Harry Hawker, whom I taught to fly and who became such a famous test pilot and whose name is perpetuated in Hawker Siddeley. Harry Kauper, who became a skilled engineer and was Works Manager in the early days at Kingston. Harry Busteed who joined Bristols served in the R.N.A.S. and R.A.F. and now lives in retirement in Cornwall. And E. Harrison who was to be a star performer on Bristol Boxkites.

The Royal Flying Corps was formed in April 1912 and later that year I was approached by a major in the Scots Fusiliers with a deep booming voice who wanted to join the R.F.C. Unless he held an Aviator's Certificate within the next 10 days he would be over age to join, and he asked me if I could get him through his tests in time. He was successful—"Boom" Trenchard—who was to become the Father of the R.A.F.

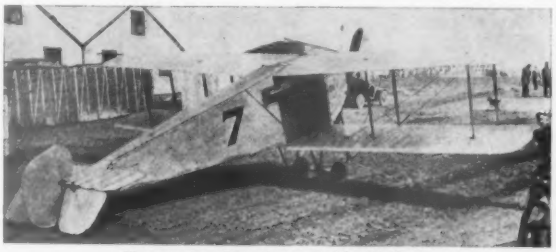

FIGURE 9. The Avro Cabin Biplane.

In order to discover the most suitable aeroplane for military use the War Office held a competition open to aircraft manufacturers the world over on Salisbury Plain in August 1912. There were prizes totalling £10,000 open to the world and some for British aircraft and pilots only. Among the pilots competing were Harry Busteed, Eric Gordon-England who is also here tonight, Howard Pixton, Jimmy Valentine, Wilfred Parke, S. F. Cody, Billy Moorhouse, Sidney Sippe, Gustav Hamel, Freddy Raynham, Maurice Prevost, who was to win the first Schneider Trophy contest the next year (1913), Gordon Bell and Pierre Verrier.

I was the pilot of a biplane designed by W. O. Manning (who designed my first Howard Wright) and built by the Coventry Ordnance Co. This firm was one of the components which eventually merged into the English Electric of today.

The competition went on for nearly a fortnight, but they failed to find an aeroplane suitable for military use. Eventually the first prize open to the world, was awarded to Cody who beat the rules by his ingenuity and dogged persistence.

Geoffrey de Havilland was designer and pilot to the R.A.F.—which meant Royal Aircraft *Factory* then—and so was barred from taking part in the Trials. But his BE proved itself the most suitable machine for military purposes when he flew it unofficially through all tests with the other participants. His was the best aircraft and thereby showed that he was in the front rank of designers. I regret to say I was not among the prize winners this time—I was handicapped by lack of power for a heavy biplane which I could not get above 700 feet.

During the trials Wilfred Parke flying an all-enclosed Avro biplane (Fig. 9) got into a spin, recovered and landed safely. This was one of the first two enclosed

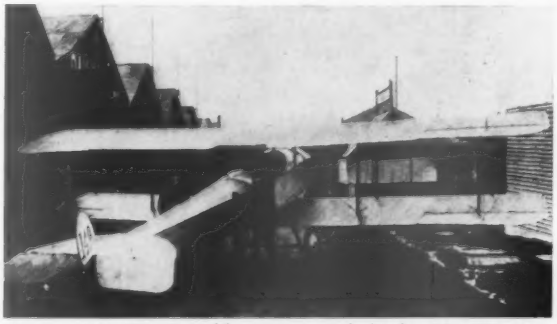

FIGURE 10. The Sopwith two-seater, built for Mr. Winston Churchill.

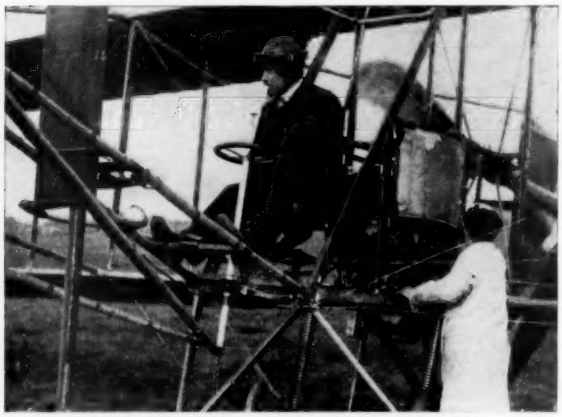

FIGURE 11. Colonel Cody and his Cathedral.

aircraft ever built—the other being an Avro monoplane. Some time later Spenser Grey of the Naval Wing was flying a little biplane like this (Fig. 10) we had built for Winston Churchill—then First Lord of the Admiralty—his passenger was Gerry Aldwell and they got into a spin. Although the aircraft was pretty well wrecked they got out of it alive to tell what happened. Eventually Professor Lindemann (later Lord Cherwell) a boffin at Farnborough, learned to fly so that he could investigate spins and he taught us a lot. It was he who deciphered exactly what happened aerodynamically in a spin and told us what to do to recover.

After the trials Cody became officially "Colonel" Cody. The popular Press confused him with the other Cody, Buffalo Bill, who was a Colonel in the United States. And they insisted on calling S. F. Cody "Colonel Cody".

When King George V gave orders to send him a telegram congratulating him on his success, the Palace staff evidently consulted the popular Press rather than the Army List for they addressed the wire to "Colonel S. F. Cody." When he received it he was delighted and declared "Well, if the *King* says Colonel Cody, Colonel Cody it shall be."

Cody's aeroplane was one of the biggest of its day (Fig. 11) and the popular Press dubbed it Cody's Cathedral because of its size. But the technically-minded people of the day explained loftily to the common herd that the real reason was because the wings had a slight droop on the ground known either as an anhedral or kathedral angle—an ingenious but far fetched explanation which was not the right one.

In September 1912 after a series of unexplained accidents to monoplanes in the R.F.C., the War Office decided this type must be inherently dangerous. In a panic they banned further flying in monoplanes by serving officers and it was some years before they repented and made an honest aeroplane out of the monoplane.

About the time of the Military Trials I was starting my own aviation firm. Here is our first Sopwith aeroplane known as the Sopwith-Wright Tractor (Fig. 12). We had bought a skating rink in Kingston for our works and there we built a fuselage to carry pilot and passenger and fitted it with wings copied from the Burgess-Wright and powered by the 70 h.p. Gnôme from the Blériot. It was very lightly loaded and therefore had a very low landing speed. Later we sold it to the Admiralty and I asked Oliver Swann, who was second-in-command to Murray Sueter, then the head man at the Admiralty, if I could have the money quickly to pay the wages bill. For this was our first sale and we had not much in the kitty. So Swann, a man of means, very sportingly promised to pay me the £900 odd from his own account if there was any delay and get it back from My Lords of the Admiralty in God's good time. But, in fact, My Lords paid up quickly so there was no need for his generosity. In due course the Tractor was taken to Eastchurch where its most useful purpose was flying regularly to Whitstable to fetch oysters for the Naval Mess.

The Aircraft Industry owes a very deep debt of gratitude to Murray Sueter—the father of all naval flying—whose death occurred a few months ago. It was largely—if not entirely—due to his support for privately built aircraft in the years before the First World War that there remained a nucleus of designers and constructors to blossom into the Aircraft Industry who were to play—may I say—a not insignificant part in the survival of our country and of the free world.

In February 1913 there was an Aero Show at Olympia. We showed a three-seater Tractor with 80 h.p.

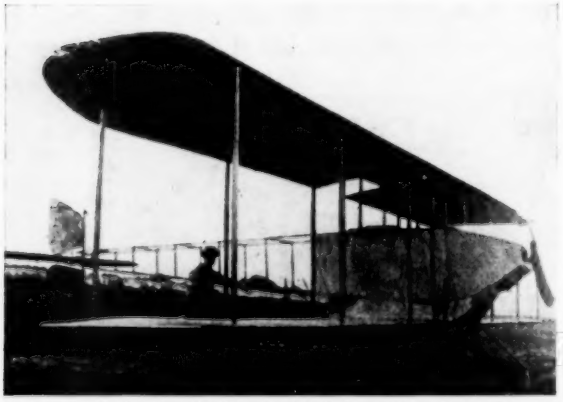

FIGURE 12. The Sopwith Tractor biplane (70 h.p. Gnôme), 1912. The first Sopwith type.

FIGURE 13. The three-seater Tractor (80 h.p. Gnôme), 1913.

FIGURE 14. The Batboat Amphibian (100 h.p. Green) which won the Mortimer Singer prize in 1913.

Gnôme (Fig. 13) and a flying boat with 90 h.p. Austro-Daimler, both aircraft built at the skating rink in Kingston, and both were acquired by the Royal Navy.

I more or less gave up active flying in 1913 as the affairs of the Company were taking all my time. So I left the flying mainly to Harry Hawker and Freddy Raynham.

I was delighted to see my old sparring partner Gustav Hamel win the 1913 Aerial Derby. That year the course was slightly longer, a hundred miles, going out as far as Epsom Racecourse in the South and Hertford in the North. Gustav flew a Morane, a very clean fast monoplane from the brain of Leon Morane who had made his name as a pilot of Blériots. Gustav covered the circuit at 75 m.p.h.

The next year he was to lose his life bringing a new and faster Morane from Paris for the race. His engine failed over the Channel and he was drowned. His body was later seen floating and identified by fishermen, but was not recovered.

In 1913 too, our aircraft established a number of British records, mostly with Harry Hawker as pilot. There was a duration record of 8 hours 23 minutes. Then a height record for a pilot alone of 11,450 ft. and he went even higher with a passenger to 12,900 ft. With two passengers he reached 10,600 ft. and then struggled up to 8,400 ft. with three passengers.

And he was successful in winning the Mortimer Singer prize for an amphibian, in a Batboat (Fig. 14) with a 100 h.p. Green. The prize was for a series of six out-home flights from a point on land, alighting on the water five miles away, returning to come down on land at the starting point—repeated five times, six in all. A height of 750 feet had to be attained during each flight. The whole business had to be completed in five hours, but he made it in 3 hours 25 minutes. The prize stipulated that everything must be British.

In August 1913 we entered a Tractor biplane on floats (Fig. 15) for a race for a *Daily Mail* £5,000 prize round the coast of England and Scotland, touching Dublin and back to England, starting and finishing at Southampton. For many reasons the number of entries was finally whittled down to three—ourselves with Harry Hawker as pilot, Jimmy Radley and Frank McClean. A powerful rival and popular favourite was to have been S. F. Cody. He had built a new larger machine on floats powered by a 100 h.p. Green. No one knew much about stresses in those days. Cody's airframe just was not strong enough and when he was making a final test flight at Farnborough, before taking it to Southampton to fit floats, the wings broke and he and his passenger, a well-known Oxford and Hampshire cricketer—W. H. B. Evans—were killed.

Cody's death came as a profound shock, not only to us of the aeronautical community, but to the whole nation. His name was a household word and he was regarded as everyone's friend. He was beloved in aviation for his kindness and sense of humour. He called his magneto his "magnuisance" and electricity to him was "electrickery"—and you cannot say fairer than that. He was a lot older than most of us pilots, being 46 when he began flying aeroplanes in 1908 and was 51 when he was killed. May be it was for the best that he died at the height of his fame, for soon afterwards aviation was to develop into a more exact science where I doubt if he would have fitted. He was a true pioneer of the trial and error school and did much to put British Aviation on the map.

In the event, the race was a fiasco and our machine with Harry Hawker was the only starter. His Tractor seaplane had a 100 h.p. Green and his fellow Australian Harry Kauper went as passenger-mechanic. The only other two remaining entries were Frank McClean's Short with 100 h.p. Green and a biplane designed by Gordon England and Jimmy Radley, with 150 h.p. Sunbeam. But neither the Short nor the Radley-England were able to start. On the first day Hawker flew to Yarmouth with a stop at Ramsgate to refuel. Unfortunately he collapsed soon after going ashore at Yarmouth from the effects of exhaust fumes and was compelled to abandon the attempt.

His machine was sent back to the starting point and was fitted with long exhaust pipes to discharge the gas well abaft the pilot and passenger and Hawker and Kauper had another go on 25th August.

They forged steadily ahead, going by way of Ramsgate, Yarmouth, Scarborough and Seaham to Beadnell (just short of Berwick) where they stayed the night after flying 495 miles. The next morning they flew by Montrose and Aberdeen and to Cromarty, the most Northern point and then cut down the Caledonian Canal to Oban, badly buffetted by gusts off the hills, the flight of 94 miles to Oban taking nearly three hours. They decided to stay the night at Oban after covering 341 miles.

Next morning they took off for Dublin and when within sight of their objective the engine power fell off

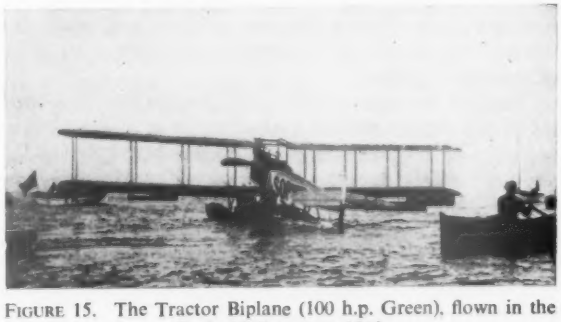

FIGURE 15. The Tractor Biplane (100 h.p. Green), flown in the *Daily Mail* contest, 1913.

FIGURE 16. The two-seater Tabloid Biplane.

Courtesy of the Imperial War Museum

FIGURE 17. The production single-seat Tabloid or Scout (80 h.p. Gnôme).

rapidly, so Hawker decided to alight and investigate. When near the sea his foot slipped on the rudder-bar, a wing-tip dipped in the water and the biplane crashed. Hawker escaped unhurt, but Kauper had a broken arm and cuts on his head. That was the end of the race for 1913 and the prize was carried over for 1914, but was abandoned when war came.

Undoubtedly our greatest success before the Kaiser's war came in August 1914, was the Tabloid (Fig. 16), which first flew towards the end of November 1913. It was called the Tabloid because it was compact and small. But Tabloid was the registered trade name of a tablet marketed by Burroughs Wellcome, who took a dim view of the naming of our aeroplane, so we had to abandon the name—officially. But the name stuck and thereafter several small aeroplanes made by other firms were also nicknamed Tabloid, much to the indignation of Burroughs Wellcome who could not do anything so long as the name was not official—except perhaps take their own tabloids as sedatives.

Our Tabloid, which was renamed the Scout, was but 20 feet long with a span of 25½ feet. It had an 80 h.p. Gnôme and carried pilot and passenger with fuel for 3½ hours.

Within a few days of its first flight—things were done much more quickly in those days of wood and canvas—Hawker flew it to Farnborough and astounded everyone by climbing with pilot, passenger and full fuel to 1,200 feet in one minute, with a top speed of 92 m.p.h. and stalling at 36 m.p.h., a greater speed range than any aeroplane at that time.

Later it was converted to a single-seater (Fig. 17). The first production Tabloids had wing warping but were fitted with ailerons before production got very far. In that form it officially became the Scout and was to be the most successful single-seater scout in the early days of the Kaiser's War.

In 1914 we put a Tabloid on floats (Fig. 18), with a 100 h.p. Monosoupape Gnôme in place of the 80 h.p. Gnôme and sent it to Monaco for the second Schneider Trophy Contest. Needless to say we were late in finishing the machine and it was only a few days before the race that it was ready for its first flight—it then had a single central main float and two wing tip floats. The main float was too far aft and directly Pixton started to taxi the machine cartwheeled and sank. This was at the mouth of the Hamble river where Faireys now build their boats. We pulled it up the beach as the tide rose and when the tide receded it was standing on the nose of the float and the propeller with the tail up in the air. We dismantled it, took it back to Kingston, cut the main float in halves and made it into two floats, built a new twin-float chassis—flew it off the river at Kingston (without permission) and shipped it to Monaco, all in three and a half days.

The French were confident of holding the race with their fast Deperdussin, Nieuport and Morane-Saulnier monoplanes fitted with 160 h.p. Gnômes for they did not fear two Americans nor a pair of Swiss in flying boats and they refused to take our biplane seriously.

Harry Hawker had taken the original Tabloid home to Australia to demonstrate, so I engaged Howard Pixton to take his place as pilot. Picky, as we called him, was a superb pilot and a very simple sort of chap with a slight impediment in his speech. He is alive and well to this day, living in the Isle of Man.

The only other British competitor was Lord Carbery who later dropped his title preferring to be known as John Carberry. He intended to fly a Morane Saulnier, but crashed it before the contest, so got hold of a Dep and made his first flight in it in the actual race. He was forced to give up after one lap because of engine trouble.

Then Picky went off in the Tabloid and after the first 50 km. the French were astonished to find the derided biplane lapping 23 m.p.h. faster than their best monoplane ; it finished the course at an average of 87 m.p.h. The French and everyone else saw it was hopeless to go on after that and conceded the Trophy to Britain.

As I have already told you, Picky was a simple sort

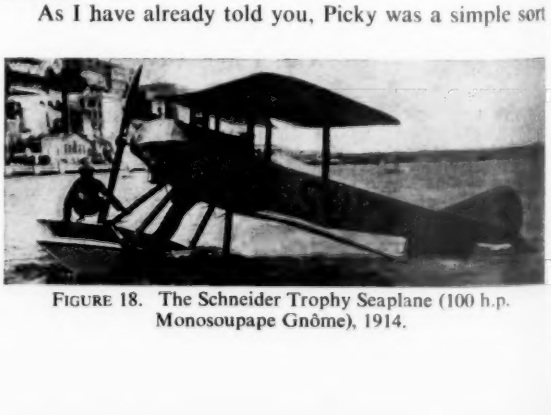

FIGURE 18. The Schneider Trophy Seaplane (100 h.p. Monosoupape Gnôme), 1914.

of chap and when Jacques Schneider invited him to celebrate his win in the Sporting Club and asked what he would like to drink—with visions of magnums of the best champagne—Picky just mumbled casually "Thanks very much. Mine's a small Bass".

When the Kaiser's War came in August 1914 we had no less than seven types of aeroplanes ready for war service, almost entirely for the R.N.A.S. to begin with, for the R.F.C. were in the pocket of the Royal Aircraft Factory. But I think six Tabloids had been delivered to the R.N.A.S. before war came.

From our works we had ready:

The Schneider ... ... 100 h.p. Mono-Gnôme

The Scout (Né Tabloid) 80 h.p. Gnôme

A two-seater Tabloid ... 80 h.p. Gnôme

(A pusher biplane on floats with 100 h.p. Anzani and machine-gunner in the nose was sold to Greece in 1914 (Fig. 19). A land version developed later was known as the *Gunbus*. Six were commandeered by the British Government when war came.)

Batboat. At the outbreak of the war these had 225 h.p. Sunbeams. Germany bought one Batboat just before the war.

Two-seater seaplane ... 100 h.p. (radial) Anzani

Two-seater seaplane .. 225 h.p. Sunbeam

As soon as war came we went into mass production of aeroplanes which was an entirely new venture for us, as for everyone else. We built a new factory in Canbury Park Road, Kingston and Fred Sigrist brought all his great engineering ability and know-how into play to improvise and gradually bring to a fine art this mass production.

When the war ended in 1918, 11,237 aircraft of our design had been built by us and sub-contractors for the British air forces and a further 5,000 for our Allies. Just as in Hitler's War the Hawker Company were constantly striving and succeeding to give the R.A.F. something better than the enemy's best, so in 1914 until 1918 we were constantly striving to keep the R.N.A.S. and R.F.C. one jump ahead of the enemy.

The R.N.A.S. had to come to the help of the R.F.C. in the Battle of the Somme with Pups and Triplanes. For the R.F.C. were sticking to the Farnborough Factory's BE2's, RE7's and 8's and FE2b's and 2d's. The R.F.C. had a few odd Bristol Scouts attached to BE squadrons mainly for the C.O. to amuse himself with rather than as fighters. The R.F.C. had one or two squadrons of the de Havilland 2 pusher Scouts, as they were called, although they were indeed formidable fighters with 100 h.p. Mono-Gnôme and there were squadrons of Vickers Gunbuses also with Mono-Gnômes.

The R.A.F. fighters—the Factory that is—were the FE8 pusher Scout and the SE5a which did great work when the war was nearing its close.

Incidentally, the naming of Factory aeroplanes is

FIGURE 19. The Greek Seaplane (100 hp. Anzani).

not without interest. FE was for Farman Experimental according to the Official history of Farnborough. The FE1 was Geoffrey de Havilland's second successful aeroplane, which was of Farman type with front elevator. The Factory bought this from de Havilland for £400 on the initiative of the Superintendent, Mervyn O'Gorman, who also brought de Havilland in as Designer Pilot.

BE was Blériot Experimental because the "Master Minds" at the Factory insisted Blériot made the first successful Tractor—even though it was a monoplane and the BE was a biplane.

SE was originally Santos Dumont Experimental because the first Santos Dumont aeroplane was a "tail-first" or canard type and the SE1 was a crashed Blériot reconstructed as a tail first job. It was highly dangerous and eventually killed Theodore Ridge. The SE1 was the only tail-first SE and the rest of the series were Tractor Scouts. The official history says that thereafter the designation was modified to Scout Experimental. It was believed in the R.F.C. that SE stood for Sopwith Experimental and there was justification for that for our 1913 Tabloid was the first successful fast Tractor biplane.

RE was Reconnaissance Experimental. There was also TE for Tatin Experimental, a pusher with propeller behind the tail, named after Tatin, who with Louis Paulhan built an aeroplane of that kind. But I do not remember a Factory TE reaching fruition.

The first of the famous series of our single-seat fighters after war came was the Pup (Fig. 20), which flew in 1915 and went into big production in 1916. It was a small light biplane weighing 1,210 lb. with 80 h.p. Le Rhône, a rotary like the Gnôme, the makers of which eventually merged with Gnôme. Many pilots of those days still look back to the Pup with nostalgia and say it was the loveliest aeroplane ever to fly and there were several Pup squadrons on the Western front.

Then came the Triplane (Fig. 21) which first flew in May 1916 and was affectionately known as the Tripe or Tripehound. A Tripehound squadron was one of the first R.N.A.S. squadrons to go to the help of the hard-pressed R.F.C. in France in 1917, at the time the Richthofen Circus was playing havoc with the BE's and FE's. With a 110 h.p. Clergêt, yet another French rotary, the Tripehound had a top speed of 112 m.p.h. at 6,500 feet. The narrow chord, 3 ft. 3 in., gave the pilot, with his head on a level with the centre plane, a better view than he got from biplanes. And with the narrow chord the shift of the centre of pressure was small compared with monoplanes and biplanes, so a

FIGURE 20. The Sopwith Pup (80 h.p. Le Rhône), 1915.

FIGURE 21. The Triplane (110 h.p. Clergêt), 1916.

FIGURE 22. The 2.F.1 Camel (130 h.p. Clergêt).

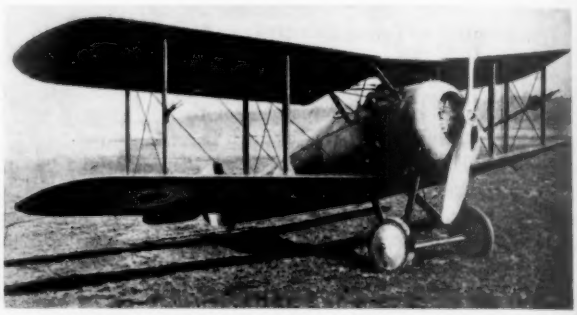

FIGURE 23. The Snipe (200 hp. Bentley Rotary 2 engine).

shorter fuselage was possible giving increased manoeuvrability. Both Pup and Tripehound had but one gun apiece, so the rate of fire with an interrupter gear to fire through the airscrew was slow.

The next single-seat Scout, or fighter as they were now called, was the Camel (Fig. 22), so named for the hump forward of the cockpit where two machine guns were housed. It had a heavier and more powerful 130 h.p. Clergêt, which gave it gyroscopic properties that made it a bit tricky. But once a pilot mastered the Camel he could do anything with it. A few Camels had the first Bentley Rotary 150 h.p. designed by W. O. Bentley, (yet to win fame with cars), the 110 h.p. Le Rhône, and 150 h.p. Gnôme Monosoupape.

The last single-seater fighter to see service in the Kaiser's war was the Snipe (Fig. 23) with 200 h.p. BR2, which stayed one of the R.A.F.'s (the Royal Air Force, not the Factory now) most dependable fighters for many years after the war was over and some people will remember the Snipe formations at the Hendon R.A.F. Displays in the mid-1920s and in post-war Aerial Derbies.

The Snipe had a top-speed of 120 m.p.h. at 10,000 feet, which it could reach in 9 minutes. Its landing speed was 40 m.p.h.

Our first war aircraft, just before the Pup, was a two-seater, the One-and-a-half Strutter (Fig. 24) named for its peculiar wing-strut system with normal outer struts and half-struts connecting the fuselage and inner bay of the top wing. Three flew as seaplanes just before the Pup and about 6,000 were built as land planes. It was a formidable fighter with a synchronised gun for the pilot firing through the airscrew and a movable gun in a seat aft of the pilot for a gunner to protect the tail. Its performance was better than any other two-seater on either side. One of the first One-and-a-half Strutter squadrons to go to France was commanded by Major Sholto Douglas, now Lord Douglas of Kirtleside, who took it to France after forming it at Stirling.

In addition we built several others, some of which were only prototypes and some went into small production. For instance, there was the Dolphin (Fig. 25) designed to make use of the big production of French Hispano-Suizas. When the Armistice came it was in big production in the U.K. and France, about 1,500 being built. Then there was the Cuckoo, first with 200 h.p. Hispano-Suiza, and production types with Sunbeam Arab and Wolseley Viper; a torpedo carrier for the Navy (Fig. 26), which was designed at the request of Murray Sueter and which was built under subcontract by Blackburn's, Fairchild Shipbuilding and Engineering Co. of Glasgow and Pegler's of Doncaster. Production was too late for this type to become properly operational before the war ended.

FIGURE 24. The two-seater One-and-a-half Strutter (110 h.p. Clergêt).

FIGURE 25. The Dolphin (200 h.p. Hispano Suiza).

FIGURE 29. The Bulldog (360 h.p. A.B.C.).

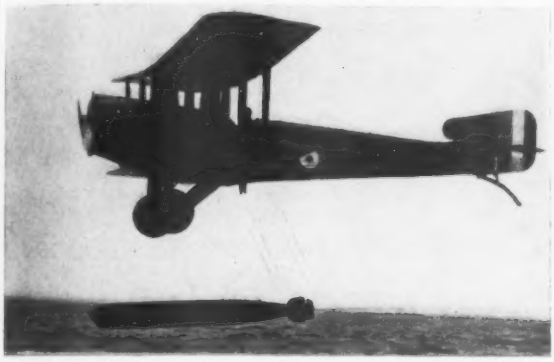

FIGURE 26. The Cuckoo Torpedo Carrier (200 h.p. Sunbeam Arab), 1918.

FIGURE 30. The Rhino (220 h.p. B.H.P.), 1917.

FIGURE 27. The Salamander (200 h.p. B.R.2) about to leave for France on 9th May 1918.

FIGURE 31. The Hippo (200 h.p. Clergêt), 1917, with T. O. M. Sopwith in the cockpit.

FIGURE 28. The Buffalo two-seater (230 h.p. Bentley).

FIGURE 32. The Sparrow (45 h.p. A.B.C. Gnat).

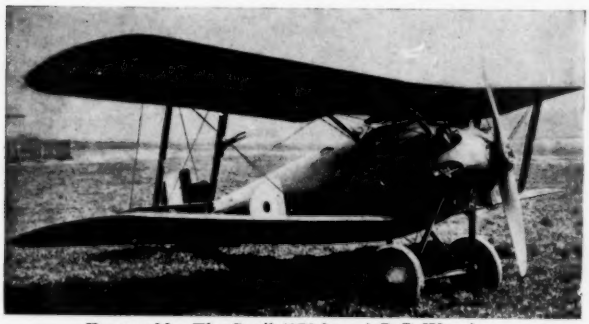

FIGURE 33. The Snail (170 h.p. A.B.C. Wasp).

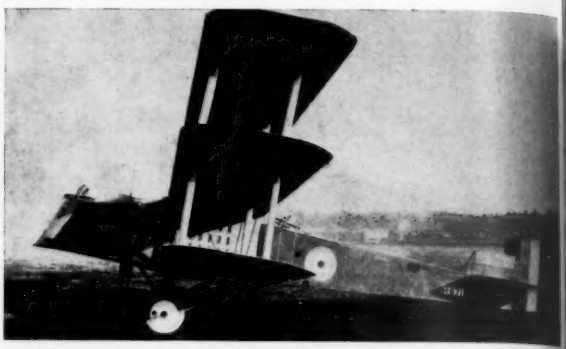

FIGURE 37. The Cobham Triplane (two 230 h.p. Siddeley Pumas), 1920.

FIGURE 34. The B.1 Bomber (200 h.p. Hispano Suiza), 1918.

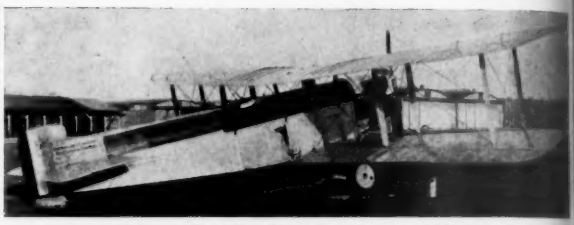

FIGURE 38. The Atlantic Transport (375 h.p. Rolls-Royce), 1919.

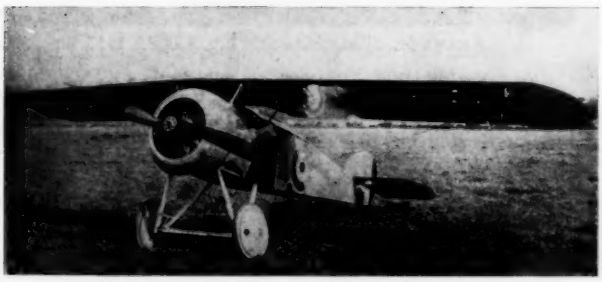

FIGURE 35. The Scooter (130 h.p. Clergêt).

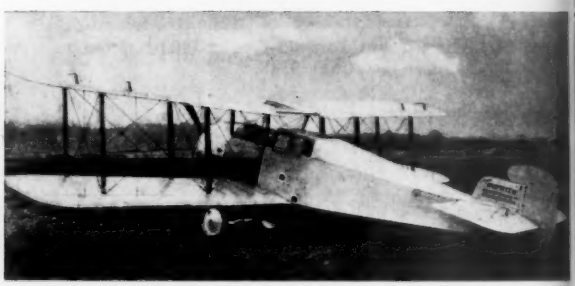

FIGURE 39. The Gnu (200 h.p. B.R.2).

FIGURE 36. The Swallow (110 h.p. Le Rhône), 1918.

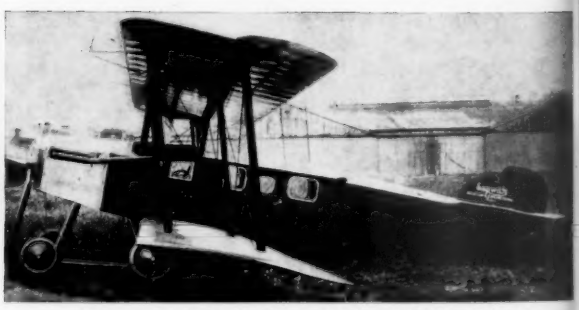

FIGURE 41. The Antelope (200 h.p. Wolseley Viper).

FIGURE 40 (*left*). The Dove (80 h.p. Le Rhône), 1919.

FIGURE 42. A photograph taken in December 1918 at the Ham Works of the Sopwith Aviation Co. Ltd. Altogether more than 400 aeroplanes are on the floor, with, in the foreground, the fuselages of six Snipes.

FIGURE 43. The Duiker (400 h.p. Bristol Jupiter), 1923. The first Hawker aircraft.

The Salamander (Fig. 27) with a BR2, was armour-plated and designed for low trench straffing. Incidentally, the word straffing, now part of the English language, derives from a sabre-rattling speech by the Kaiser when he cried "Gott Straf England". And when the young pilots of the R.F.C. fired off ammunition left over into the German trenches on their way home from sorties they lightheartedly called it trench straffing and later it became a specific hazardous duty.

The Buffalo (Fig. 28) was a two-seater counter-part of the Salamander.

Among a mixed bag are the Bulldog (Fig. 29), Rhino (Fig. 30), Hippo (Fig. 31), Sparrow (Fig. 32), Snail (Fig. 33), B1 Bomber (Fig. 34), Scooter (Fig. 35) and the Swallow (Fig. 36). The Scooter was made of Camel spares and used by Harry Hawker as a run-about. This proved so useful that the Swallow was specially designed for Harry and was composed of existing parts of more advanced aircraft.

During 1919 we built the Snapper, Snark, Dragon and Grasshopper, and another bomber, the Cobham Triplane, named after the nearby village of Cobham (Fig. 37) with two Pumas.

When the war ended we carried on for a year or so and built the Atlantic (Fig. 38) on which Harry Hawker and Kenneth Mackenzie-Grieve made their Atlantic attempt; and the Wallaby a shorter-range version of the same machine in which Matthews and Kay made an attempt to fly to Australia, but were dogged by bad weather and gave up in the Dutch East Indies. Then there were the Gnu (Fig. 39) and the Dove (Fig. 40), the latter a two-seater pacified version of the Pup. And the last Sopwith aeroplane was the Antelope (Fig. 41) with Viper engine made by Wolseleys, with two passengers in a roomy cabin and four wheel undercart and brakes.

By the middle of 1920 it was obvious that with no orders from the R.A.F., and civil aviation in its birth-pangs, we could no longer carry on. We had to pay enormous taxes to the Exchequer, so I told my board that we must wind up while still solvent, which we did.

And in September 1920 we formed the Hawker Engineering Company, almost the same day as Geoffrey de Havilland formed the de Havilland Aircraft Company after the Aircraft Manufacturing Company run by Holt Thomas, which built the successful series of DH Aircraft during the war, had called it a day and ceased to function.

What we did was to wind up the Sopwith Company while still solvent and in its place and in the same works we brought the Hawker Company into being with Harry, Fred Sigrist, Bill Eyre and myself as Directors.

We thought it better to make a completely fresh start and drop the old name, so that there could be no confusion with the Sopwith Company in liquidation and we named it after Harry Hawker who had done such great work throughout the war as test pilot.

Our object was to keep it a small firm; to make aircraft when there was a demand and keep the wheels turning by building motor cycles and a few other odd jobs.

The first Hawker Aircraft was a monoplane, the Duiker (Fig. 43). But Harry did not live to see it fly, as he was killed in the Goshawk, a biplane built by the British Nieuport Company, which he was to fly in the 1921 Aerial Derby, designed by that same Harry Folland who founded Folland Aircraft, one of the later firms to join the Hawker Siddeley Group.

I said just now that it was our intention to keep it small, but things happen and look at the damned thing now.

And what of the future?

Boys of my generation grew up reading Jules Verne's *Clipper of the Clouds*, H. G. Wells' *War in the Air* and those wonderful imaginative stories of air fighting appearing weekly in the boys' paper *Chums*, by Frank Shaw, who later served in the R.F.C. So I suppose the seeds of aviation were planted in our minds that way.

Boys of today grow up reading space fiction. Surely they are the youngsters this learned Society should now have their eyes on. The imaginations of these boys are being fired by their reading and as they reach adolescence space travel is beginning to be a reality and is taken out of the realms of fiction. From such boys will surely come the space-farers of the future who will lead men into the realms of outer space.

And it is a solemn thought that *even* if man can ever travel at the speed of light (186,000 miles a second), we shall only be able to go pottering about locally among the planets of our own Solar system or visit two or three of the nearer stars only a few light years away. And at a penny a mile, the lowest charge ever for mechanical transport, you would need a pretty fat expense account to reach the Moon for £1,000 and the same to come home. And if you want to visit the nearer planets the single fare to Venus would be £100,000 and to Mars about double that. So even pottering locally about the inner planets of our own solar system will be pretty prohibitive financially.

Well, we must look to the youngsters of today and those yet to be born to reach outer space—and sort out the economic problems too.

I have been talking for a long time—far too long and fear that my ill-gotten ramblings have suffered from too much vitamin I, but I am afraid I found it difficult to avoid, so I will just say thank you for being so patient.

Following the Lecture Sir Thomas answered several questions. In reply to one speaker who suggested that Harry Busteed had gone into the R.N.A.S. as a Commander, Sir Thomas said that Busteed had stayed in the R.F.C. until after the formation of the R.A.F., retiring as an Air Commodore, and had then joined the R.N.A.S.

Asked how the design of early aeroplanes was calculated Sir Thomas said that there were no stress calculations at all. All the earlier aeroplanes, certainly his and most other peoples were built purely by eye; the first Sopwith type that got nearest to stressing was the Tabloid.

In reply to a question as to who was the Chief Draughtsman for the Tabloid, Sir Thomas said it was rather a family affair but he would give most credit to Harry Hawker. Hawker had "had a crack at it," Fred Sigrist had a crack at it, he had had and all the boys in the shop had had a crack at it but he thought Harry Hawker was the chief instigator.

A speaker asked if it were true that the Tabloid was, in fact, drawn on the wooden floor of the original building in Canbury Park Road. Sir Thomas replied that it all started like that in the old skating rink. In reply to another question as to whether the BS1 at Farnborough had influenced the design of the Tabloid he said he did not think so and had no guilty conscience.

Mr. Masefield: They had heard a wonderful story delightfully told, and many of those names and photographs must have struck many a chord. When Sir Thomas was speaking, he had realised that he had said that he took his ticket on the 22nd November 1910, almost exactly fifty years ago. To look back and see people who had been starting on a new element in man's conquest of affairs throughout the world was a salutary affair, and what great flights they were in those frail aeroplanes, with not terribly reliable engines. One wondered how many of the names Sir Thomas had mentioned were remembered today. Many of them were not, he was afraid. But on the other hand, there was a revival of interest in history which might be a great thing in days to come. He would ask Colonel Preston to propose a vote of thanks to Sir Thomas.

Colonel R. L. Preston (Chairman of the Historical Group Committee, *Associate Fellow*): No greater appreciation could be shown to Sir Thomas for his most interesting lecture than the fact that some of the most famous people in aviation were present to hear him. Many of the people whom Sir Thomas had mentioned in the lecture were present and that alone was a great tribute to him.

This was a wonderful start to the lectures of the Historical Group. They hoped to have a number of them and he hoped that many of those present would join the Historical Group.

One point of interest, as Mr. Masefield had said, was the fact that all Sir Thomas's lecture had been recorded and would be kept by the Royal Aeronautical Society. From now on they planned to record the history of the pioneers as told by themselves.

He would ask them to record in the usual way their sincere thanks to Sir Thomas for his interesting and wonderful lecture.

Dr. Moult: He had enjoyed this lecture tremendously because he had sat back and relaxed while Mr. Masefield had done all the hard work: he was sure that everyone would like to thank Mr. Masefield for the very nice way, as usual, in which he had done it.

He now had a pleasant duty to perform, which Mr. Masefield had already mentioned. When the Historical Group of the Society was started it was decided to make a catalogue of historic machines and historic engines, and members of the Group had done some excellent work in checking all the references and the authenticity of everything. Some very busy Saturday afternoons and Sundays had been spent in helping to restore these old machines and, as the Chairman had said, volunteers were still welcome! It had been agreed that a plaque should be awarded to each of the machines that measured up to the required standard and should be attached thereto. The plaque was necessarily small and neat because the payload of these old timers was very restricted!

He had very great pleasure in presenting this first plaque to be issued by the Royal Aeronautical Society to Sir Thomas Sopwith. The note accompanying the award read as follows:—

> "This is the first plaque to be presented by the Society for mounting on one of the aircraft on the Register of Historic Aircraft. It is for the only surviving example of the 160 h.p. Sopwith tri-plane fighters built during the First World War. This precious survivor, built 43 years ago by Oakleys of Ilford, has just been refurbished by Hawkers at Dunsfold on behalf of the Air Ministry to whom it belongs. The Company has made a splendid job of this work and it is especially fitting that the first plaque should be presented to this aircraft. The purpose of the plaque is to encourage the owners of these historic aircraft to look after them. In this, the Air Ministry and Hawker Aircraft have set a fine example to other owners."

Sir Thomas Sopwith: He would be very happy to pass this on and see that it was suitably installed in the aircraft, and thanked them very much indeed. It was greatly appreciated.

Dr. Moult: They had all tremendously enjoyed hearing Sir Thomas's story. He had told of his side of British Aviation 50 years ago at a time when most of the great companies of this country were establishing themselves. Indeed, 1960 was the jubilee year and they were privileged to be able to have a first-hand account from the great pioneers themselves. Sir Thomas had told a story of aviation when aviation was really aviation and they were most indebted for this story and record.

Solid Propellant Rocket Motors

BY

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1. Introduction

A solid propellant rocket motor consists essentially of a propellant charge in a container fitted with an expansion nozzle and igniter. Since, before a rocket motor can be designed, it is necessary to have some knowledge of the properties of the propellant to be used, a description will first be given of the propellants which are currently available.

NOTATION

A	area of burning surface of propellant, in.^{2}
a	ratio of mass of propellant to total mass
g	acceleration due to gravity, ft./sec.^{2}
I	specific impulse, lb. sec./lb.
M_B	mass at all burnt, lb.
M_P	mass of propellant, lb.
M_T	initial mass, lb.
R_b	rate of burning of propellant, in./sec.
t	time of burning, sec.
V_{max}	maximum velocity, ft./sec.
ρ	density of propellant, lb./cu. in.

2. Propellants Available

The two main classes of solid propellant used today are usually termed double-base and composite. The distinction, which is largely historical, is made according to the nature of the chemical system used. If the oxidiser is a solid crystalline material, such as ammonium nitrate or ammonium perchlorate, the propellant is " composite "; if the system is mainly nitroglycerine and nitrocellulose, essentially in a gelatinised form, then the propellant is usually termed " double-base." However, these distinctions are now largely for convenience, since double-base propellants may contain solid oxidising salts and composite propellants may contain nitroglycerine or similar esters as plasticisers. The principal solid propellants under current investigation in the United Kingdom are double-base propellant either in an extruded or cast form; plastic propellant, which is a putty-like composite propellant and, more recently, polyurethane propellant, which is an elastomeric, or rubbery, composite.

2.1. MANUFACTURING PROCEDURES

Essentially, in the manufacture of all these propellants, the various ingredients are mixed either as a slurry or as a type of dough. The machines used are conventional, and similar to those employed in the bakery and confectionery trades. However, special precautions have to be taken to prevent violent impacts and it is usual to conduct the mixing in relatively small batches of not more than a few hundred pounds. After mixing, the processes become dissimilar. Double-base propellant of the cordite type is extruded, by large presses, into the required shape. It is then inhibited on the outer surface, by some suitable non-inflammable material. The charge is loaded loosely in the rocket motor. Double-base propellant of the cast type is first extruded into small grains, or cylinders, which are poured into a special mould. Casting liquid, a desensitised nitroglycerine mixture, is then introduced, and the whole charge " gelled " by keeping at an elevated temperature for a few days. These charges are also inhibited, like extruded cordite, and are loaded loosely into the rockets. Plastic propellant, which, after mixing, has the consistency of a stiff putty, is first deaerated and then formed into shape in the actual rocket motor tube by extrusion or compression moulding. This propellant is bonded directly to the rocket motor tube, and hence requires no inhibition on the outer surface.

Polyurethane propellant, after mixing, has the consistency of a cream, and is poured directly into the motor tube. It is then "cured" by holding at a slightly elevated temperature for a few days. This propellant is also bonded directly to the motor case, and after curing has the appearance of a stiff rubber, similar to that of a motor car tyre.

In the plastic and castable composite propellants the fuel-binder must have special properties. In the case of plastic propellant it must be a highly viscous liquid, with a low freezing point, whose viscosity does not change much with temperature. This ensures that the propellant does not become brittle at the lowest operating temperature and does not flow out of the rocket at the highest operating temperature. Polyisobutene, of medium molecular weight of about 10,000–15,000, satisfies these requirements and has the advantage of chemical inertness.

For polyurethane propellants the binder must be sufficiently fluid to remain pourable even when loaded with 75–85 per cent of solids. However, if it is of very low viscosity sedimentation will occur, since ammonium perchlorate is appreciably more dense than most organic binders. The oxidiser is frequently added in two or more size distributions to assist mix fluidity and some-

The 12th lecture to be given before the Astronautics and Guided Flight Section—on 6th December 1960.

times surface active agents are added as well. (Mishuck and Carleton[1].) After casting the charge is formed by polymerisation or curing. This process must take place at a relatively low temperature, and must evolve little heat. In addition, for large rockets, any appreciable expansion, or shrinkage, on cure is undesirable. Obviously also, for economic reasons, the curing time should not be more than 3 or 4 days, and the curing agents should be non-reactive with the oxidiser and other propellant ingredients.

2.2. PERFORMANCE

The factor of most importance for a solid propellant is its performance, usually defined as a "specific impulse." This specific impulse is the product of the thrust and time of burning divided by the total propellant weight burnt, that is lb.sec./lb., under certain specified conditions. Usually these conditions are: propellant operating at a combustion chamber pressure of 1000 lb./in.^{2} abs. and the gases being expanded to 14·7 lb./in.^{2} abs. This performance can be calculated from basic thermodynamic data; it can also be measured directly and usually, in a well designed rocket, the measured performance is some 90–95 per cent of the calculated value. In this paper we shall consider only the measured performances as these are obviously of greater practical significance. Table I gives some recent values.

TABLE I
MEASURED SPECIFIC IMPULSE (AT 1000 LB./IN.^{2} ABS.)

Cordite	190 - 210
Double-base cast	190 - 215
Plastic propellant	170 - 235
Polyurethane propellant	200 - 235
Ammonium nitrate types	180 - 220

The performances quoted are limited by various factors. In the case of cordite, the limitation is imposed by the thermodynamic properties of nitroglycerine and nitrocellulose and by the essential requirement of producing a composition which can be gelatinised and extruded. Double-base cast propellant has the same thermodynamic limitations, but can cover a somewhat broader range because the composition does not have to be extruded. The performance of plastic propellant is limited by the oxidiser available, ammonium perchlorate, and the need to cover a wide range of burning rates. So far slow burning rates have been achieved only at the expense of performance. Polyurethane propellant is limited again by the oxidiser, and by the necessity to retain a pourable system, which involves a fairly high liquid content initially. Ammonium nitrate types are seen to be of limited performance, and interest has lapsed in these propellants, except for special applications such as gas generators where weight is not of prime importance.

Another factor of great practical importance is burning rate. Generally, double-base propellants burn at rates between 0·3 and 1·0 in./sec. at 1000 lb./in.^{2}; the slower burning propellants usually have a degraded performance. Composite propellants, based on ammonium perchlorate burn at between 0·1 and 1·0 in./sec. at 1000 lb./in.^{2} abs., and the slower rates are again achieved only by degrading performance. For instance, the plastic propellant used in the Skylark experiments has a measured specific impulse of only 200 lb. sec./lb., which is considerably lower than the 230–235 achievable by the best plastic propellants. This has been discussed at length by one of us in a recent paper[3].

In the search for improved performance attention has been given to the addition of light elements or hydrides. Most of the likely substances present considerable practical difficulty, since they are very reactive or unstable. Some success has been achieved by the addition of aluminium metal to composite propellants. This has enabled the performance of both plastic and polyurethane propellants to be raised to about 235 lb. sec./lb. without noticeably increasing burning rates. It has, however, greatly increased the combustion temperature, and as the exhaust also contains alumina there are severe practical problems in nozzle design.

The search for alternative oxidisers has also been pursued. Lithium and potassium perchlorate have slight theoretical advantages, but have proved inferior to ammonium perchlorate. Nitronium perchlorate has recently been announced as available by Callery Chemical Company[4] and theoretically should enable specific impulse to be increased. It is a very reactive chemical, rather unstable and very hygroscopic, so there are again very serious practical problems in its use. Boron hydrides, with light metals have also been mentioned, but present even greater difficulty because of toxic products and extreme reactivity.

2.3. MECHANICAL PROPERTIES

In the case of loose, or cartridge loaded, charges the propellant need not have a high elongation, but must have a high modulus and tensile strength. For plastic propellant, the material must be capable of flow sufficient to accommodate the differential thermal expansion between the propellant and the rocket motor case. In practice the elongation is about 200 per cent, and the tensile strength is very low, usually about 10–20 lb./in.^{2} when measured at normal rates. At fast rates of strain, plastic propellant acts similarly to a rigid material, since there is a time-dependent factor in the flow equation. In the case of elastomeric propellants, the elongation need not be as high, but it is generally accepted that a minimum of 30 per cent at 0°F, when measured at one in./in./min., is required. The tensile strength need not be very high; about 100 lb./in.^{2} is now thought to be adequate. Thor Smith[2] has pointed out the importance of the strains produced in a propellant on cooling from the cure temperature. The strain produced on ignition can also be very important, especially in thin walled rocket motors.

2.4. STORAGE AND AGEING

Most practical rockets, especially those for Service use, have to be stored for varying periods before being fired. At elevated temperatures there is frequently degradation of the polymer, or reaction with the ingredients of the propellant. In some cases, as for

example in double base propellants, this process can be slowed down by the addition of a stabiliser. The reactions involved frequently yield volatile products which may cause the charge to crack or to cause porosity so that the ballistic properties are adversely affected. In some cases atmospheric oxygen or water vapour may produce a surface layer which is difficult to ignite. At low temperatures crystallisation of the binder may occur; this is usually a slow process and can be detected only after prolonged storage at the low temperature.

In a few cases, of which the most well known is that of ammonium nitrate, polymorphic changes occur in the oxidiser. These phase transitions are accompanied by volume changes, and repeated cycling through the critical region may ultimately cause the charge to crack.

2.5. CURRENT DEVELOPMENT

The greatest interest at the present time is the increasing size of solid propellant rockets. It is general knowledge that both the Polaris and Minuteman American rockets are powered by solid propellants, and these rockets are in the size range formerly thought of as the sole province of liquid propellants. It is obvious that for such large rockets extrusion processes would be uneconomical, and that a plastic material might be unsuitable. Hence attention is being given to propellants which can be slurry cast, and which are case-bondable. The two most favoured systems are those based on the Thiokol polysulphide synthetic rubber and on the polyurethane rubber. The latter type has special interest in the United Kingdom since the basic ingredients are more readily available, and are capable of covering a wider range of physical properties. The curing reactions take place at comparatively low temperature and with little heat evolution. Consequently the manufacture of large rockets is much simplified. It will be appreciated that for these costly rockets the manufacturing procedure must be very exact and capable of producing material fully complying with specifications. Ballistic control must be exact; this requirement can be met by the use of the Crawford strand burner and of small test rockets cast at the same time as the large charge. The strand burner is essentially a pressure vessel immersed in a thermostatically controlled water bath in which propellant strands can be burned under a series of selected pressures. The strands are inhibited on the outer surface and are pierced transversely by two thin wires a known distance apart. The strand is ignited and the time taken for the propellant to burn the distance between the two wires is measured with an electrical chronometer. A number of strands from the same batch of propellant are burned and with suitable precautions reproducible results can be obtained. The burning rate obtained is not normally exactly the same as that obtained in the motor, but once the correct strand burning rate for a given application has been established the strand burner serves as a very convenient method of control. If the strand burning rate turns out to be incorrect then, in the case of non-curing propellants like cordite and plastic propellant, the correct burning rate can be obtained by blending fast and slow burning batches, but in the case of propellants which have to be cured, *e.g.* polyurethane propellants, the batch must be scrapped.

In America there is interest in continuous processes of manufacture, which are almost completely remote controlled. Suggestions have been made that very large rockets might even be filled on site.

3. Motor Design

While a designer of military rockets is concerned not only with motor performance but with many other matters such as motor behaviour in different environments, motor reliability and so on, this paper concerns itself mainly with motor performance as it is this which is of prime importance in the recently developed field of ballisic missiles and vehicles for space research. The other factors mentioned will only be lightly touched upon or in some cases omitted altogether.

3.1. MOTOR PERFORMANCE

In many applications a rocket motor is used as a boost and its performance can be judged by the velocity it will impart to a given mass. For vertical flight this is given by the well known equation

$$V_{\max} = Ig \log \frac{M_T}{M_B} - gt - \text{drag correction.} \quad . \quad . \quad . \quad (1)$$

Where $V_{\max}$ velocity at all burnt
I specific impulse of propellant
g acceleration due to gravity
M_T initial mass of vehicle
M_B mass of vehicle at all burnt
t time of burning of rocket motor.

It will be seen from the gt term that it is best to keep the time as short as possible. The drag, however, is proportional to ρV^2 (where ρ = density of the air) so that velocity is lost if the vehicle moves too fast at low altitudes. Problems of kinetic heating would also be encountered if the velocity is high enough. Furthermore, the rocket vehicle and the instruments it contains may not be able to withstand a very high acceleration. As in most fields, therefore, it is necessary to compromise. For the present purpose the last two terms on the right-hand side of the velocity equation can be neglected, as in practice they are always prevented from being too large.

In a gravity-free field, equation (1) becomes

$$V_{\max} = Ig \log_e \frac{M_T}{M_B} \quad . \quad . \quad . \quad (2)$$

If it is now assumed that a propellant of the maximum specific impulse has been chosen for the application in mind, then for the most efficient design it is necessary to make M_T/M_B as large as possible.

Since, if M_p = mass of propellant,

$$\frac{M_T}{M_B} = \frac{M_p + M_B}{M_B} = \frac{M_p}{M_B} + 1$$

and M_B is the mass of rocket at all burnt plus the payload weight, which is fixed, it is clear that the problem is to associate the maximum mass of propellant

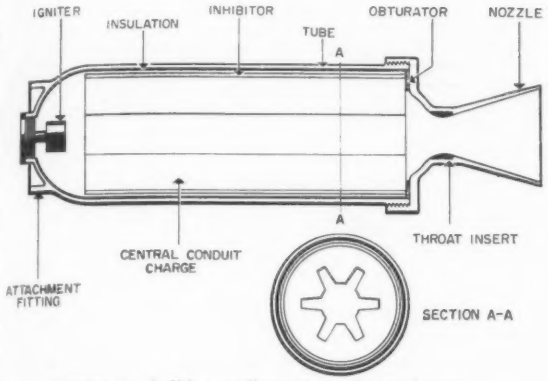

FIGURE 1. Solid propellant motor, loose charge.

with the minimum mass of motor hardware. One of the steps in doing this is to get the maximum amount of propellant in the minimum space. Two factors are involved here:

(*a*) volumetric loading density,
(*b*) propellant density.

3.2. VOLUMETRIC LOADING DENSITY

The early cordite rockets had "loose" charges and, as will be seen from Fig. 1, contained much waste space and an appreciable amount of inert material. Modern high performance motors use case-bonded charges (*see* Fig. 2) and contain no waste space. The only space not filled with propellant is the conduit. At the same time, weight is saved by the use of a bottled end which avoids the need for large diameter screwed, flanged or similar joints.

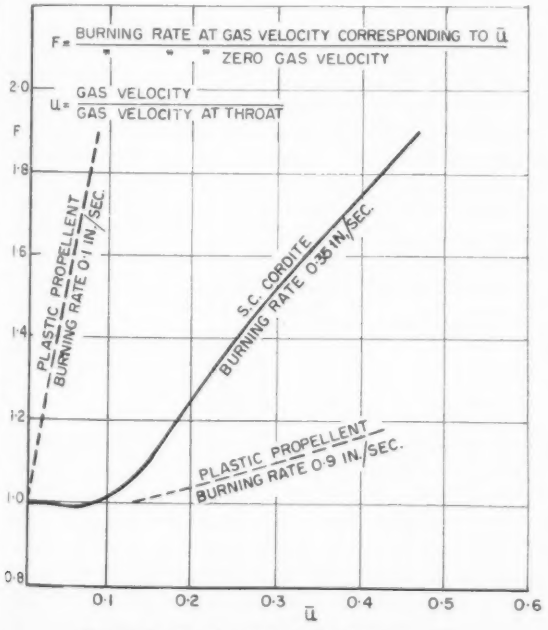

FIGURE 3. Erosion ratios as a function of $\bar{u}$ (pressure = 1,000 lb./in.²).

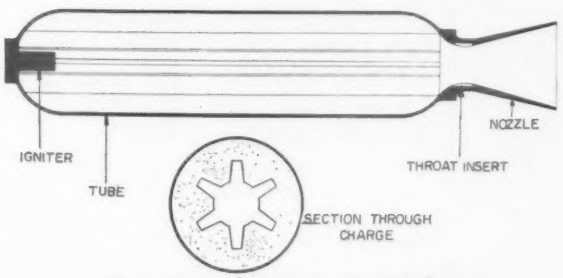

FIGURE 2. Motor with case-bonded charge.

It is clear that, having arrived at a case-bonded charge, it is necessary to:

(*a*) reduce the conduit volume to a minimum,
(*b*) make sure that the propellant all burns efficiently.

There is clearly a limit to the reduction in size of the conduit, and the area of the cross-section at the nozzle end must always be greater than the cross-sectional area of the throat. As the cross-sectional area of the conduit is reduced the gas velocity increases and causes the propellant to burn faster. This phenomenon is known as erosive burning and, as shown in Fig. 3, its effects can be quite serious. Increases in burning rate normally occur at much lower gas velocities with slow burning propellants than with fast burning propellants. The erosive effect disappears as the conduit increases during motor burning and the gas velocity falls. When present, erosion manifests itself as a peak pressure which occurs on ignition and is known as an "erosion peak."

It is clear that the amount of gas flowing down the conduit is less at the head end and this suggests tapered conduits as a means of increasing loading density. Tapered conduits sometimes introduce manufacturing difficulties and an alternative solution which yields most of the benefits of a tapered conduit is a conduit with one or more "steps" in it.

Most rockets are required to operate at constant pressure and this means that the area of the burning surface must be kept constant. A few ways of doing this are shown in Fig. 4.

The most commonly used charge design is the star-centre design. It will be seen, however, that all star-centre designs give slivers which burn out at low pressure and these lead to impulse losses. These losses are appreciable at low altitudes but are quite small at high altitudes, because performance depends on the ratio of the combustion pressure to external pressure rather than on combustion pressure alone. Sometimes the propellant goes out when the sliver region is reached and the pressure drops suddenly. The losses can then be quite serious. For example, if the slivers remain unburned in a high alitude research vehicle like Skylark there is not only a loss of total impulse but the weight of the unburned slivers is added to the payload. Losses due to this effect can be reduced by the use of artificial slivers made of a material having a much lower density than the propellant.

Some charges are sliverless and the rod and cylinder shown in Fig. 4 is a simple example of one of these. The

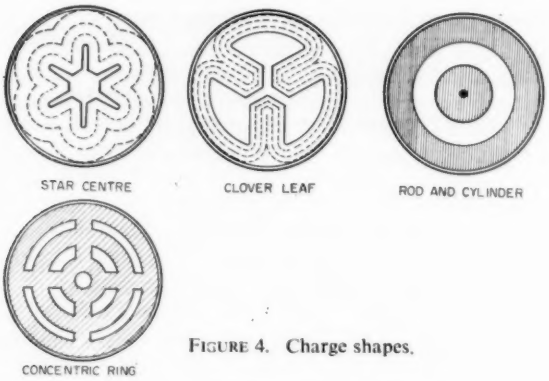

FIGURE 4. Charge shapes.

support of the central cylinder, however, presents certain difficulties and this design is not much used. A more popular design is the slotted tube shown in Fig. 5. Here the decrease in burning surface of the slotted part of the charge is used to compensate for the increase in burning surface of the cylindrical part. At the same time, by putting the slots at the nozzle end of the motor it is possible to get a stepped conduit.

The wide variety of charge shapes sometimes puzzles those not familiar with rocket motor design. It is mainly a consequence of the fact that the thrust of a solid propellant rocket motor is given by the equation

$$\text{Thrust} = I\rho R_B A \quad . \quad . \quad (3)$$

where I = specific impulse of propellant (lb. sec./lb.), ρ = density of propellant (lb./cubic in.), R_B = rate of burning of propellant (in./sec.) and A = area of burning surface.

This means that, ignoring comparatively small variations in I and ρ, which are not independent variables but accompany the choice of a propellant of given burning rate, the only quantities the designer can vary to get the required thrust are the propellant burning rate and the burning surface. As mentioned earlier there is a relatively narrow range of burning rates available to the designer and this means that he needs a wide range of charge designs to give him the necessary variation in burning surface. The perimeters of star-sections of charges giving constant pressure burning are of necessity very close to the perimeter of the tube as a consideration of the shape at web burn-out will show. The slotted tube charge design is useful in having a small area of burning surface and a thick web, and this renders it particularly suitable for motors required to give a relatively small thrust for a long time.

In discussing the problem of putting the maximum amount of propellant into a given volume, no mention has yet been made of the cigarette burning charge which at first sight seems to be clearly the best way of achieving this objective, as no space is required for the conduit. In practice, however, the situation is not quite as favourable as it appears, because the motor tube near the nozzle end is exposed to the hot propellant gases during the whole of the burning period and all of the motor tube is exposed for a part of the time. This contrasts with the case-bonded motor with a central

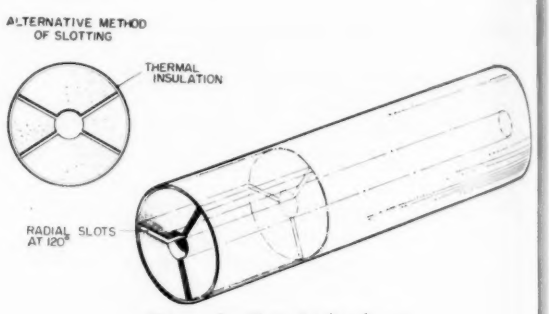

FIGURE 5. Slotted tube charge.

conduit, where the tube is insulated from the hot gases by the propellant itself until the very last stages of burning. This means that the inside of the tube of a cigarette burning motor has to be lined with an insulating material which reduces the propellant loading density and adds to the inert weight. Quite apart from this, cigarette burning motors are of limited application because, with the small burning surface they present and the limited burning rates which can be achieved with existing propellants, it is not possible to obtain sufficient thrust for many applications. There are other disadvantages, such as the limited length/diameter ratio which can be used because of the differential thermal expansion of the charge and case which can cause failure of the propellant motor tube bond on temperature cycling.

3.3. PROPELLANT DENSITY

The second means of increasing the mass of propellant which can be loaded into a given space is to increase the propellant density. It is easy to see, however, that if an attempt is made to choose ingredients to increase the propellant density it is necessary to watch the effect they may have on specific impulse, and it is clearly of interest to know the relative importance of specific impulse and density. This can be fairly easily done by making appropriate substitutions introducing propellant density into equation (1), differentiating and equating the velocity change to zero, when the change in propellant density which is equivalent to a small change in specific impulse is readily found. The results are shown in Fig. 6 for the case of a single stage missile of constant volume required to boost a given payload to a given velocity, and are derived from the equation

$$\frac{d\rho}{\rho} = \frac{dI}{I} 2{\cdot}302 \frac{1}{a} \log_{10}(1-a) \quad . \quad . \quad (4)$$

where ρ propellant density
a mass of propellant/total mass.

It will be seen that when the mass ratio is high, as in a ballistic missile (say 0·90), it takes about 2·5 per cent improvement in propellant density to compensate for a loss of one per cent in specific impulse. For the boosts of a medium range ground to air anti-aircraft missile, however, where the ratio of boost propellant mass/total missile mass may be of the order of 0·3, a small improvement in propellant density is nearly as valuable as a small improvement in specific impulse.

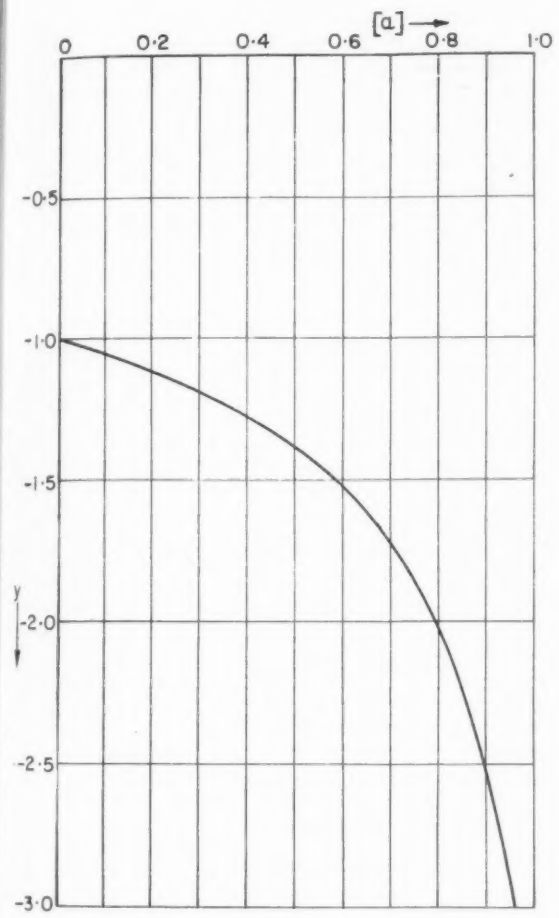

FIGURE 6. Variation of $y = 2{\cdot}3026 \frac{1}{a} \log_{10} (1-a)$ with a.

For the first stage of a two stage ballistic missile, in which the second stage is an appreciable fraction of the weight of the first (*e.g.* Polaris), the mass ratio is low and an improvement in propellant density assumes an importance approaching that of an improvement in specific impulse.

Having considered how to get the maximum amount of propellant into the minimum volume attention can now be turned to the problem of cutting down the weight of the motor body containing the propellant, and of the expansion nozzle.

3.4. MOTOR HARDWARE

In trying to reduce the weight of the hardware, materials are needed which have high mechanical strength and low density to reduce the weight of the stress bearing components and materials having good thermal insulating properties to prevent the stress bearing components in regions of the motor likely to get hot from losing their strength through overheating. These insulating materials, including the nozzle throat, must also have some powers of resistance to chemical attack by the hot propellant gases. The nozzle insert presents a special problem as any change in the throat diameter represents some lack of control over the motor operating pressure.

The material most favoured for the stress bearing components is high tensile steel. Many current motors in the United Kingdom are made from a chromium molybdenum steel which is wrapped and welded and then heat treated to give a 0·1 per cent proof stress of about 67 tons/in.^{2} and an ultimate tensile strength of about 80 tons/in.^{2} There is a continual search for suitable steels of higher and higher tensile strength and alloy steels giving ultimate tensile strengths of more than 100 tons/in.^{2} are now available for rocket motor manufacture. A choice of a suitable steel is not a simple matter. Tensile strength alone is not enough and sensitivity to stress concentration such as might arise from tilting or mismatch of welded parts must be carefully studied. When using very high tensile steels it is desirable to avoid longitudinal welds altogether and one method of doing this which is popular in the U.S.A. is to build up the body from flow turned segments.

There are various other materials which have been applied with more or less success to the manufacture of rocket cases; among these are resin-bonded fibre glass, steel tape and titanium alloys. Winding methods are attractive for large diameter motors as they avoid the need for very wide sheets of metal or the heavy equipment for flow turning. All methods of manufacture, however, have their particular problems.

Plastics have very low thermal conductivities and form the basis of most rocket insulating materials. In places where dimensional changes can be tolerated, such as in blast-pipes or the entry sections of nozzles, they can protect the stress bearing components of the motor from the hottest gases for considerable periods of time. Pyrolysis and ablation of the exposed surface occurs and the thickness of the insulation required naturally increases with the severity of the conditions and the duration of firing. The most commonly used plastics are thermo-setting resins of the phenol-formaldehyde type and these char under the action of heat and produce a layer of hard carbon which is moderately erosion resistant. The thermal decomposition of the heated surface generates gases which pass through the charred surface to produce a measure of boundary layer cooling. Furthermore, most of the decomposition reactions which occur are endothermic and are therefore an additional aid to cooling.

In order to provide sufficient mechanical strength in the insulant, and also to help to bind the charred surface layer together, it is necessary to add some reinforcement to the plastic. This usually takes the form of an inorganic fibre such as asbestos, glass or silica. The reinforcement melts or dissociates at the hot gas surface and may help to protect the char.

Reinforced plastics are often used in the expansion cones of long burning rocket motors, sometimes forming the complete structure and in others serving as an insulating lining for a metal shell. Ablation is, of course, not a desirable phenomenon in an expansion cone which

should be of fixed dimensions, but the conditions are not so severe as in the nozzle approach section and ablation occurs less rapidly.

While it would be very nice if thermal insulants were not required in rocket motors, their use does not detract from the motor performance quite as much as would appear at first sight. A good proportion of the thermal insulant will have disappeared by the end of the motor burning time and thus the mass ratio of the motor is better than is at first suggested. At the same time the decomposition products are added to the jet efflux and increase the total impulse of the motor.

As is well known, the heat transfer conditions in a rocket motor are most severe at the throat. Furthermore appreciable dimensional change at the throat cannot be tolerated and therefore reinforced plastics are, in general, unsuitable. The materials which have been proposed, and in some cases used, as throat materials fall into the following classes (*i*) various forms of carbon, (*ii*) ceramic materials, (*iii*) refractory metals.

Since, in any but the shortest burning motors, the surface of the material in the nozzle throat will closely approach the stagnation temperature of the propellant gases, the first requirement of the nozzle material is that it should have a high melting point. This rule need not be obeyed for very short burning motors because, if the nozzle insert material has a high thermal conductivity and the nozzle insert has a sufficiently high thermal capacity, the surface temperature may not reach the melting point in the burning time.

The second requirement of a nozzle material is that it should resist thermal shock. The rate of rise of heat transfer at the nozzle throat is extremely rapid when the motor is fired, and the thermal stresses set up can cause catastrophic failure in many materials.

A third requirement is that the nozzle throat material should be resistant to chemical attack. Nearly all solid propellants are fuel rich and give combustion products containing some carbon monoxide, which would normally be regarded as reducing. However, as long as any water vapour is present many materials can be oxidised at the temperature of rocket gases. Other chemical reactions can also occur.

Carbon exists in a variety of forms which vary widely in their behaviour as nozzle materials. Pyrolytic graphite has greater oxidation resistance than other forms and has been quite widely used as a nozzle material.

Ceramics have, on the whole, been somewhat disappointing materials due mainly to their brittleness and susceptibility to thermal shock.

Of the refractory metals, molybdenum has been the most widely used and is in general satisfactory for all but the hottest propellants. For the very hottest propellants tungsten and alloys of tungsten with other refractory metals, such as molybdenum and tantalum, are being used.

In general, it can be said that the ideal nozzle material suitable for use with all propellants in all applications has not yet been found, although an acceptable material can usually be found for a specific requirement.

3.5. SHAPE OF MOTOR BODY

The ratio of the weight of propellant to weight of hardware is clearly dependent on the shape of the motor body. From a purely pressure vessel point of view a spherical rocket motor is theoretically attractive and it is clear that a long thin motor is bad because, as a motor containing a given amount of propellant is lengthened, the ratio of conduit volume to total volume becomes greater and greater and little space is occupied by propellant. Spherical motors have been proposed from time to time and even made, but there are filling difficulties and sliver losses and the shape is inconvenient for many applications. With cylindrical motor bodies the nozzle end plate is usually heavy and, therefore, short fat motors have relatively heavy hardware. In practice, length/diameter ratios of 4–8 give good ratios of propellant weight/hardware weight. The shape of the motor is, however, often controlled by other factors, such as missile requirements and burning time.

3.6. SUSTAINER MOTORS

The fundamental principles which need to be followed in designing high performance motors have so far related to boost motors. A little consideration will show that essentially the same principles apply to sustainer motors, whose purpose is to maintain the velocity of a missile, already boosted to the required speed, by exerting a thrust of sufficient magnitude to overcome air drag. Here, again, it is necessary to associate the maximum amount of propellant with the minimum amount of hardware, for otherwise the motor and the missile will be heavier than they need be. This will lead to the need for larger boost motors and larger control surfaces, which in turn will lead to more drag.

3.7. IGNITER

A small, but important, aspect of solid propellant motor design is the design of the igniter. Despite a number of attempts to solve the problem theoretically, the design of igniters remains an essentially empirical process. The igniters in small rockets consist essentially of an electric squib surrounded by a fast burning pyrotechnic powder in a light metal housing, and ignition and rise to the working pressure occurs in an interval of time measured in milliseconds. For larger motors powder igniters tend to be too violent and slower burning devices, such as pellets of pyrotechnic composition, are often used. Too large an igniter can produce a pressure peak on ignition and too small an igniter can produce failure to ignite at low temperatures. It is very much a case of not too little and not too much.

3.8. COMBUSTION INSTABILITY

Only passing reference can be made to the problem of combustion instability which sometimes causes the motor designer much trouble. Under certain conditions and with certain propellants and charge designs it has been found that oscillations can occur in the gases in the conduit of a motor which can become so violent, and cause such a large increase in burning rate of the propellant, that motor failure results. This is usually called resonance. It is sometimes triggered off by the

igniter, and a sporadic form of instability of this kind was experienced in the early stages of development of the Raven motor and was cured by redesign of the igniter. Other cures for resonance are the incorporation in the propellant of a fuel, like aluminium, which will give solid combustion products, the use of resonance rods and the modification of the geometry of the charge or motor body. The first two cures are believed to work by acoustic damping and the third method is intended to discourage those modes of oscillation which cause the instability.

3.9. THRUST VECTOR CONTROL

For ballistic missile and satellite launching vehicles using solid propellant motors it is necessary to have some form of thrust vector control. This is because the velocity at take-off is insufficient for aerodynamic controls to be effective and, in any case, a great deal of the controlled flight occurs in an atmosphere which is too rarefied to supply any useful control forces. It is, therefore, necessary to have some means of deflecting the rocket jet. Various methods have been tried among which are the use of jet vanes, as in the V-2, and the use of a tubular extension which can be swivelled in any direction at the exit of the rocket motor. If the latter method is used there must be some supplementary form of roll control, *e.g.* by small auxiliary jets. If the rocket motor has four nozzles, as in Polaris, then the required control forces can be obtained by deflecting each rocket jet in one plane only. There are clearly material problems to be solved in all methods of jet deflection.

3.10. THRUST CUT-OFF

In ballistic missile applications, and in some satellite launching applications, it is necessary to cut-off the thrust when the vehicle has reached a certain velocity. It would appear that the most accurate way of doing this may be by the explosive opening of ports suitably placed at the head of the motor. At the moment of opening these ports the net thrust of the motor acts in the reverse direction to the direction of flight and the motor separates smartly from the payload.

4. Quality Control and Inspection

The task of a rocket motor development scientist or engineer does not end when he has produced a satisfactory design which has been proved to work reliably. He must also establish procedures of quality control and inspection which will ensure that all motors subsequently manufactured are of equal quality and performance.

The components of the rocket motor body are inspected by methods similar to those used for components in other branches of the engineering industry, but inspection of the propellant charge presents special problems. The success of a solid propellant motor depends largely on ensuring that burning occurs only on those surfaces where it was designed to occur and that no uncontrolled increase in burning surface, such as might arise from flaws or cracks in the propellant, or separation from the motor wall in the case of a case-bonded charge, can occur. For detection of flaws visual inspection of the motor conduit with a boroscope, X-rays and radio-isotopes are commonly used. For detecting lack of bonding of the propellant to the motor walls ultrasonic methods are normally used.

It will be observed that the problems of achieving high performance are to some extent opposed to the problems of achieving high reliability. High performance demands small factors of safety and the minimum amount of thermal insulation, whereas high reliability demands large factors of safety and more than adequate thermal insulation. Improved quality control and inspection can do much to ensure that both objectives are met at the same time.

5. Solid Propellant Motors and Space Research

Solid propellant motors have not yet played more than a subsidiary part in space research. This is mainly because, for the same payload and the same number of stages, they invariably turn out to be heavier than their liquid propellant counterparts. In addition, until quite recently, the size required for the first stage of a vehicle to launch even a satellite of moderate size was much larger than anything of which there was experience.

It is interesting to note that solid propellant motors have mainly been used for the upper stages of space vehicles which, from the point of view of an efficient design, is just the wrong place to use them. A bad staging ratio for the last stage reflects right back to the first stage. However, solid propellant motors are very convenient for staging and clustering and it was probably this and the lack of availability of suitable liquid propellant motors which caused their adoption.

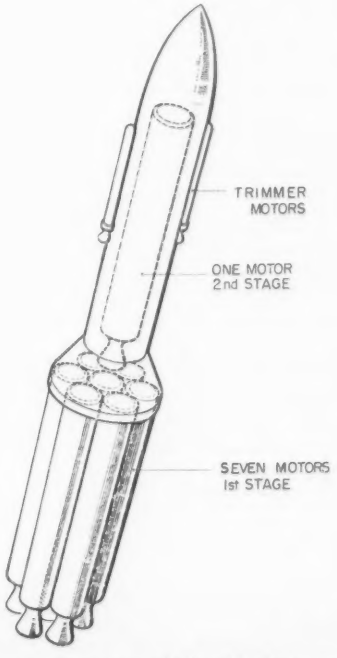

FIGURE 7. Two-stage missile with cluster motor.

FIGURE 8. Construction of a large solid propellant motor from segments.

Recently it occurred to various people in the U.S.A. that even though the first stage of a large space vehicle would be heavier if a solid propellant were used rather than liquid propellant it might nevertheless be cheaper. Such a booster would probably be used with liquid propellant motors in the upper stages. Accordingly, N.A.S.A. issued contracts to a number of American firms to study the feasibility of making large solid propellant motors and to examine the logistics.

There is, of course, a serious handling and transportation problem with large solid propellant motors containing a million or more pounds of propellant, and several methods have been proposed for overcoming these.

The first is known as clustering and amounts to putting together a number of units in a bundle. It is illustrated in Fig. 7, which is in fact a diagram taken from a design study of a solid propellant version of Blue Streak made some years ago. The main problem is in designing a light-weight structure to hold the motors together.

The second method consists of making the motor in a number of segments which can be put together on the firing site, and is shown in Fig. 8. It is clear that the joints between the segments involve some weight penalty, but how serious this is cannot at present be stated.

The third method has already been mentioned and involves casting the propellant into the motor body on the site, which would be a major operation.

So far as the relative costs of comparable liquid and solid fuel motors are concerned the conclusion of one contractor was that the solid propellant motor was a little cheaper than the liquid, but the comparison was very sensitive to the assumptions made. The propellant in a solid propellant motor is very much more expensive per pound than that of its liquid counterpart, but this is more or less offset by the high cost of the hardware in a liquid propellant booster. In the case of very large liquid or solid propellant motors, which will only be used in small numbers, the development cost may well be of the same order as that of the motors produced. Nobody has yet been able to decide which kind of motor would be least expensive to develop.

Considering these very large motors raises the question whether the ratio propellant weight/hardware weight changes with motor size. The answer is that, if the motor insulation and the joint between motor body and nozzle are ignored, a solid propellant motor scales very nearly exactly. If thermal insulation is taken into account, it is likely that the weight of thermal insulation in relation to the total motor weight will decrease somewhat with increase in motor size, and this will mean that large motors will have somewhat more favourable mass ratios than smaller ones.

It is clear that mass ratio depends on motor operating pressure. Specific impulse also depends on motor operating pressure; there must therefore be an optimum operating pressure for any particular motor, and this will depend on whether it is to be used at ground level or altitude. In principle, very low operating pressures are possible at high altitude because the specific impulse depends mainly on the ratio chamber pressure/external pressure rather than on chamber pressure alone.

For a large booster motor starting at ground level a mass ratio of 0·90 should be readily achieved, and 0·92 seems possible. An upper stage solid propellant motor should achieve 0·93. These figures compare with, say, about 0·94 for large first stage liquid propellant motors. The estimates of mass ratio for solid propellant motors have been derived from the propulsion requirements only, *i.e.* treating the motor body as a pressure vessel. When assembled into a vehicle various flight loads have also to be taken into account and these could conceivably modify the picture, although it seems probable that if the upper stages were lightly pressurised for structural stability all would be well.

6. Conclusion

In conclusion it may be said that, apart from paper studies, this country has confined most of its activities in the solid propellant motor field to military rockets of modest size. Here great emphasis is placed on the ability of the motors to function under a wide range of climatic conditions, to stand up to long term storage and to survive rough usage resulting from transport and handling. If a requirement should arise for motors for ballistic missile or space applications some of these limitations on the propellant chemist and motor designer will disappear and this may enable the use of propellants and methods of construction which were previously unacceptable.

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SUMMARY OF DISCUSSION

Mr. Cleaver (*Chairman*) said he would like to hear some argument about the relative merits of the different propellants. He called upon Dr. Johnson of E.R.D.E. to open the discussion.

Dr. Johnson said he did not wish to raise any technical matters, but he thought those present might be interested to know a little about the early history of rockets. British rocketry had been largely developed by William Congreve

Jnr. who by 1805 had made some quite good ones which were tried out against the French coastal defences. The Army formed rocket brigades and one of them did well in the later stages of the Peninsular War. Another fought at Waterloo where the records said they fired 52 rockets. These were rather unreliable especially if fired at high elevation. By 1812, by which time Congreve had become a Fellow of the Royal Society, he was designing 8 in. solid propellant rockets weighing about 3 cwt., so clearly he had made considerable progress. In 1814 he published a memoir entitled "The Details of the Rocket System," and in an earlier account had given a rather neat description of the rocket which stated "it is ammunition without ordnance; it is the soul of artillery without the body." Congreve died in 1828, and it was an interesting fact that little more was done for military rockets for about 100 years.

Mr. Page asked about the performances of the propellants and the temperature limits of the propellants quoted in the paper.

Dr. Young replied that the question of specific impulse depended very much on the assumptions made. In the paper it was assumed that the combustion pressure was 1,000 lb. per square inch and that the gases were expanded to ordinary atmospheric pressure (14·7 lb. per square inch). Obviously, other figures were obtained if one expanded to vacuum conditions, as was the case for some space applications. Also, for any solid propellant, if one considered the highest possible burning rates, then one normally got the highest performance; but frequently these propellants were not usable in the type of application required. For example, in the case of the Skylark rocket, the actual web thickness of the propellant was only about 3 or 4 in. and this had to burn for about 30 seconds, so that one was forced to use a relatively low burning rate propellant which was of rather low performance. In other applications, where the propellant was only required. For example, in the case of the Skylark very fast burning compositions which, in general, had high performance. The figures quoted were the sort of practical values that had been achieved and were not necessarily the highest values that could be obtained under the best conditions.

Dr. Maxwell said that the low temperature limit obtainable for any given propellant system depended on many factors, such as whether the rocket would be subject to rough usage and transport at these temperatures, and on the method of ignition.

Dr. Young said that, in general, the problem of meeting low temperature requirements became greater the larger the rocket. Most propellants would survive at very low temperature, but the difficulty arose that this low temperature did not persist indefinitely and the charges tended to crack when warming up. In some cases, on long storage at low temperature, the binder tended to crystallise and then, if you attempted to fire the rocket there was a very good chance that it would blow up.

Professor Smith raised the question of erosive burning. He said that the facts fitted in very neatly with simple boundary layer ideas, which would indicate that at high burning rates you ought not to get very much erosive burning.

Mr. Heron said that what Professor Smith suggested was probably true, and it was generally the case that increasing burning rate tended to reduce erosivity. As far as he was aware, however, there was no theoretical explanation which fitted all the facts at present.

Mr. Robinson said that Dr. Maxwell had emphasised the importance of reducing the weight of the inert components and mentioned the maximum tensile strength of steel available as 100 tons per square inch. He would like to know if this could be improved to, say, 150 tons per square inch, and whether he could use such a material, because it would then be so very thin for the sort of pressure range one was dealing with in the rocket motor, that it might be unable to withstand rough usage.

Dr. Maxwell replied that material of 150 tons per square inch tensile strength could be used in some applications. Not all rocket motors had to be subject to rough usage and he suggested that in space research vehicles this higher strength steel might well be suitable. Furthermore, the actual thickness depended on the temperature range of operation of the motor and, in the larger motors, the absolute thickness would probably prevent damage due to denting and scratching.

Dr. Sillitto said he would like to comment on Mr. Robinson's question. He was concerning himself with a motor for which they were very glad to be able to use steel of 140 tons per square inch tensile strength, and the thickness of the steel, even at this high strength, was about 0·14 in. These higher strength steels were clearly wanted by rocket designers.

Mr. Fischeles asked what arrangements had been made to vary the thrust of solid propellant rocket motors.

Dr. Maxwell replied that the thrust of solid propellant rocket motors was not normally capable of being varied during burning. One could build up a thrust programme within certain limits. For example, if there were a requirement to have a thrust of 10,000 lb. for 5 seconds, followed by 2,000 lb. for 20 seconds, this could be achieved, but there were no readily available means for varying the thrust during burning in the same way as there was with liquid rocket propellants, by turning the liquid on or off. Attempts had been made to vary the thrust of solid propellant motors by the use of variable nozzles, but it was rather questionable whether this was worth while.

Mr. Carton said that Dr. Maxwell had referred to the operation of second stages in atmospheric pressures tending to zero and had mentioned the utilisation of very low combustion pressures. He asked what were the limits to the combustion pressure in the circumstances? Consequently, were there any problems associated with the ignition of rocket motors at very low pressure?

Dr. Young said that one of the difficulties at low pressure was the greatly increased dissociation of the combustion gases and, as a result, the performance of all high energy propellants tended to fall off more at low pressures. It was also the case that some solid propellants did not burn well at low pressure, so that there was usually a practical limit, which varied according to the nature of the propellant. If one used pressures much below about 300 lb. per square inch there was usually difficulty in maintaining stable combustion.

Dr. Maxwell agreed that 300 lb. per square inch was about the lowest practical limit at present. Ignition at high altitude did present a serious practical problem and, in fact, it was necessary to carry out ground level tests in vacuum chambers, in order to be sure that one could ignite the motor if there were a vacuum in the conduit. Alternatively, one could seal the motor at atmospheric pressure and thus give an additional measure of assurance. Clearly, one could get failures at high altitude and the Americans in particular appeared to have considerable difficulty over this point.

Mr. Cleaver asked whether these failures of ignition of upper stage solid propellant rockets were due to the propellant, or were they electrical failures?

Dr. Maxwell replied that he had no definite information on this point but they could have been normal electrical faults.

Professor Baxter said he was very interested to hear of the advanced state of development of solid propellant rockets. He asked whether Dr. Maxwell thought that liquid propellants might be further developed if they took advantage of the advances which had been made in the solid propellant field, for instance, in things like nozzles and case design?

Dr. Maxwell replied that liquid propellant rockets had, in fact, advanced considerably and large boost motors had the remarkable mass ratio of 0·94. A lot of the improvements in solid propellant rockets had come from improvements on the engineering side and the mass ratio had considerably improved in the past 10 years.

Professor Smith asked was it the case that the only significant way of improving the performance of a rocket motor was by increasing the specific impulse of the propellant.

Dr. Young replied that this was generally true. For space applications an increase of one or two units in specific impulse might make a very big difference to the final velocity of the missile. This was the reason for the supremacy of liquid propellants from the point of space vehicle application, since they usually had rather higher performances than the solid propellants currently available.

Mr. Fischeles asked why ammonium nitrate propellants had not been mentioned?

Dr. Young replied that at the present time the main requirement for solid propellants was really performance and not cheapness. Ammonium nitrate was very cheap, but one could not obtain as high a performance from ammonium nitrate propellants as one could from those based on ammonium perchlorate. The maximum performance measured with ammonium nitrate type propellants was usually below 220. The phase change of ammonium nitrate was also a serious practical difficulty and, although ways of overcoming this had been discovered, these usually involved some sacrifice in performance.

Mr. Cleaver concluded the discussion by thanking the two lecturers for a very interesting paper.

Lt. Col. L. V. S. Blacker (*Fellow*), *Contributed*: In the discussion after Dr. Young and Dr. Maxwell's most interesting lecture, we were given some useful facts about Colonel Congreve's rocket system of 1808. My own studies tell me that Congreve was stimulated towards rocket development by the Afghan Sultan, namely Haidar Ali, who seized Mysore from its Hindu Raja. His son Tipu was the ally of the French whom they called Citoyen Tipu after their revolution, in their wars against the Honourable Company. Haidar appears to have provided the rocket with its metal casing, probably of sheet iron with a brazed seam. He must have picked up his rocket tactics from the Moghals of the Delhi Dynasty who learned them from the Chinese, who used rockets at Si-Nan-Fu, in, I believe, 1232, to repel the Mongol cavalry. Moghal is an arabic corruption of Mongol. These Chinese rockets, which anticipated our Crecy cannon by about a century, must certainly have had bodies either of paper or of female bamboo. However, despite Tipu's rockets, we stormed Seringapatam and gave Mysore back to its Hindu ruler who held it until 1947. In the India Office was a fine painting of the handing over, as wards, of Tipu's two orphan sons to Lord Cornwallis. Wellesley was prominent in the Seringapatam battle, but took a poor view of Congreve's rockets in the Peninsula in spite of some success at the crossing of the Adour in 1814. He is reported to have said that rockets are very good for setting towns on fire, but he did not happen to want to set any towns on fire.

On the other hand, in 1813, at the Battle of the Nations Leipzig, the only British unit was Captain Bogue's troop of Royal Horse Artillery (actually called "The Rocket Brigade"), later "O" Battery and still called "The Rocket Troop." He fired effectively against the French Cavalry. 132 Battery was a unit of the Bengal Horse Artillery and is known as the "Bengal Rocket Troop." In the Russian inspired war of 1878/79 rockets achieved good results against Afghan cavalry at Fattehabad in the North. In the South, however, the Afghan artillery, disregarding rockets, was much superior technically to the British field artillery because it was armed with rifled breech loading guns. The British guns were still muzzle loaders so General Primrose sustained an ignominious defeat. This was another example of Afghan technical efficiency in the realm of artillery. When guns became rifled, their accuracy was too much for the single nozzle black powder rockets of the day, which faded out. It came partially back to us at the battle of the Somme in 1916, when Lieutenant le Prieur, of the French Navy, gave us a supply of his excellent rockets, which the records show to have been propelled by Ballistite. The Royal Flying Corps fixed these to the front struts of their "1½ strutter" Sopwiths and shot so many German balloons out of the air that the German artillery was deprived of the fine observation derived from them.

The good performance of these rockets was clearly due to the initial velocity imparted by the aircraft, and also to the energy derived from their nitro cellulose propellant. The Afghans gave us another taste of their technical superiority in artillery in 1919, against General Dyer.

Students of Conan Doyle will remember that in the Maiwand disaster, Doctor Watson was struck by that Jezail bullet in the clavicle.

The Royal Aeronautical Society
The First Fifty Years—1866 and All That

BY

J. LAURENCE PRITCHARD, C.B.E., Hon.F.R.Ae.S., Hon.F.I.A.S.

"To conceive extravagant hopes of the future, are the common dispositions of the greatest part of mankind." Edmund Burker, 1728-97.

The Year 1867

The opening of the second year of the Society's existence found the Council facing the inevitable slowing down after the first waves of enthusiasm. Indeed, before the year ended, only Wenham and Brearey attended the December Council meeting, and no business could be transacted. Brearey reported that he had sent out sixty-eight letters to people who were likely to be interested, but none had shown any interest whatever.

The difficulties of keeping the aeronautical infant alive were great. Few scientists or engineers could be persuaded to believe in heavier-than-air flight, although a number lent a readier ear to the possibilities of the airship.

At the April meeting of the Council the secretary asked for instructions as to the steps to be taken with those members whose subscriptions were two years in arrears. He was facing at an early stage the primary difficulty which secretaries of learned institutions always have, to deal with those who had shown themselves unworthy of their responsibilities as members, although ready to accept the prestige of membership. I feel very strongly that if anyone asks "What would I get out of the Society if I did join?" the only possible reply is "Just as much as you put into it." *The Society should be more proud of the quality of its members than the quantity of its numbers.*

Many papers were received by the Society, most of them on heavier-than-air flight, a change from the first year's papers, which were dominated by hot air and balloon ideas, but not published. At the first general meeting of the year, held on 17th April 1867, no fewer than six papers were read and discussed. Wenham spoke "On the present state of Aeronautical Science" and emphasised the lack of knowledge of forces on bodies moving through the air, and the contradictory results of what little information there was.

"Without a definite law of the acting and counteracting forces of the elastic air," he said, "we have not even entered the threshold of aeronautical discovery, and attempts at obtaining mechanical flight cannot be foreseen in their results."

"In the present stage of inquiry," he added, "a series of experiments are much needed in order to furnish data for construction. Should these establish the law of the capability of an atmospheric stratum for supporting heavy weights by means of very slightly inclined surfaces travelling at high speeds, we shall then have a certain fact to start from; and let it be borne in mind that the air as a means of transit has in one respect an *unequalled* advantage, that of a ready-made roadway, without hills, turnings, or irregularities to damage or break machinery; consequently, the only limit to speed is not in safety, but the amount of propelling force that can be applied."

The first lecture was no more nor less than an exposition by a non-member, Mr. Henry Bright, of a patent he had taken out in 1859 for assisting the ascent or descent of a balloon by means of contra-rotating screws. Its chief claim to be mentioned at all is that the British Museum in 1861 accepted a model, together with drawings, on the grounds "that it is the first thing which has overcome gravity, and has moved, by the mechanical power contained within itself, in the opposite direction to Sir Isaac Newton's apple."

Surely there has been, so rarely, in the history of aviation, so expressive a statement as "and has moved in the opposite direction to Sir Isaac Newton's apple"! The lecturer made a remark about his ideas which equally deserves to be on record in the Society's history. "The theory," he declared, "appeared very good as long as it was on paper!"

Mr. H. C. Hurry, a member, who read the next paper, was a qualified engineer, and he also had his ideas on paper. Hurry's engineering was sound enough, but his knowledge of aerodynamics was poor even below the speed of sound. He said he believed he had discovered where everybody else was wrong, and produced an undulating wing to show how wrong he was himself.

Thinking other people are always wrong was evidently catching, for the Earl of Aldborough, who lectured on bird flight, declared, "I feel fully confident I have attained the leading objects which I have sought." One of these objects "which appears not to have been previously solved by any other person, was the solution of the problem of the mechanical action of a bird's wing upon the air."

The noble and inventive Earl took out a patent each year from 1854 to 1857, but ten years later he told members of the Society, "I have been engaged for years in the construction of an Aerial Vessel . . . . and its completion long before the present time has only been delayed by the difficulty in finding competent workmen to make the several parts, a difficulty the extent of which few can conceive who have never been engaged in such pursuits."

Judging by the large advertisements in the aeronautical papers and national press, the difficulty still exists!

In these early days the velocipede was a popular mode of travel along the roads, and a Mr. Henri Reda St. Martin proposed to attach wings to his shoulders while riding his velocipede.

"These," he told his listeners, "by a series of impulses against the ground will enable a person provided with this velocipede to travel over the land with great speed, and even to cross rivers and lakes with the same ease."

But instead of making a fortune out of the first aerial amphibian he was struck off the rolls of the Society two years later for not having paid his subscription!

Wenham, who was a regular attendant at these early meetings and a vigorous and often constructive critic, said of the lecture by Henry Bright, who had a helicopter model, "For the mere purpose of raising a weight I consider that it is wholly useless, and that many misdirected attempts that have been made to apply it in this way have been one of the greatest drawbacks to Aerial Navigation . . . . Of all things this is the most easily tried and the least satisfactory in its result."

Wenham's criticism was justified at the time, based on the great lack of aerodynamical data. But neither Mr. Bright nor Mr. Hurry allowed themselves to be browbeaten by the formidable Wenham. Mr. Bright indeed, asserted strongly that his model had actually lifted weights attached to it, and added that the time had now come when a helicopter large enough to carry a man should be constructed. It was pointed out to him that the expense might be a difficulty and the inventor replied loftily, "I think now that I have given my experience to the world the public should take the matter up." Mr. Bright became no more inspired, as the money would not fly in his direction, and Mr. Hurry came slowly to ground level.

Yet both had an unexpected champion at the meeting in James William Butler, a member of Council who lived long enough to see an aeroplane fly. He announced that at the next meeting of the Society he would produce the helicopters which he would buy on his next visit to Paris, and bring them over for the benefit of all those present.

He duly produced the "French Aerial Screw" at the next meeting of the Society on 15th July. This helicopter model had a pair of contra-rotating horizontal screws driven by clockwork, and just managed to raise itself in the air. No measure of the power exerted by the clock spring or the weight of the model was given by Mr. Butler and the *Annual Report* commented "the importance of this piece of mechanism has not served to elicit any useful information of a scientific character."

It is an odd thing how many medical men have expressed their views on flying problems, not from the biological view as one would expect, but from that of the scientist and engineer. The first paper to be read at the July meeting was by Dr. W. Smyth, on experiments practically demonstrating the Laws by which birds fly, and their application to an aerial machine. It was a subject much after the heart of the Duke of Argyll, who was in the chair, for in his classic *The Reign of Law* he had discussed the problem of bird flight. The Duke was a firm upholder of heavier-than-air machines. "I think Dr. Smyth's paper a very able one," he commented.

The lecturer deserved the commendation for he described a careful experiment he had carried out with a captive pigeon, in order to ascertain the power exerted by the bird in flight. It may justly be said that Dr. Smyth's paper was more important for the direction it gave to the value of experimental research than to the conclusions to be drawn from his own experiments. Patent No. 1392 of 1867 gives the practical outcome of his work, a cylindrical fuselage driven forward by a tractor screw and supported by a pair of flapping wings. He calculated from his pigeon experiments that he could raise a weight of 10 cwt. with a 6 h.p. motor and fly faster than any known bird!

Dr. Smyth might almost have claimed to have been the first member of the Society to have suggested the use of a retractable undercarriage for his aeroplane, for, to quote from his lecture, "The supports on which it rests are curved, so that when raised from the earth they can be turned round, and will then coincide with the body of the machine."

He roundly asserted "The screw propeller has been shown to be almost useless for the purpose of raising a weight," and drew down upon his head the violent disagreement of Mr. Bright, but to no effect. In the course of the discussion Mr. Butler announced that he and his brother directors of the Lenoir Gas Company were busy developing a petrol engine.

Dr. Smyth was not the only lecturer that evening who had drawn inspiration from the Chairman's book *The Reign of Law*, which had been published the year before the Society was founded. A Major John Scott Phillips, after due praise from the Chairman and Mr. Wenham for elucidating the principles of bird flight, announced that after six years research he was now prepared to show how these theoretical principles could be converted into mechanical practice. But some five years before his lecture he had taken out a patent, No. 2420 of 1861, for a flying machine. It was a mixture of an ornithopter and a fixed wing machine, with the virtues of neither, a view with which Wenham, in the ensuing discussion, agreed.

Wenham dominated many of these early discussions and was listened to with great attention and respect. It was to Wenham that Brearey usually referred all suggestions for lectures and papers. In the Society's possession is a notebook in which Brearey meticulously put down his expenses, and an oft recurring entry read "To Mr. Wenham with papers for perusal," or "To Mr. Wenham for proofs." The journey from Blackheath, where Brearey lived, to Clapham to see Wenham took up a considerable part of the day and cost in those days 1s. 6d. It was before the days of London Transport!

Wenham at this meeting drew attention to Henson's work of twenty five years previously and made the remarkable and erroneous statement "It is not generally known that Henson's machine was actually constructed. I believe the two planes were in length about

three times the breadth; when the machine was launched from an altitude, for want of greater length of wing, it descended only a short distance from the starting point. I believe that the whole question of aerial support and propulsion is simple, based upon the laws of action and reaction of relative weights, or that of a body supported, impinging upon a great weight of air."

Wenham was an engineer and was not deluded by theories which defied Newton's laws. In the course of his remarks he drew the attention of his audience to the effect of a jet of water or air, and for the first time in a lecture meeting of the Society, on 15th July 1867, used the now familiar words "Jet propulsion."

"It has been shown by experiment that a small jet of water issuing at a very high velocity is inadequate for propelling a steam vessel. As the size of the jet is increased, and its velocity diminished, so do we obtain a better result. It would appear then, conclusively, that for the so-called principle of jet propulsion (which, in fact, like any other principle of fluid propulsion, is merely action and reaction between two relative weights) the most favourable condition would be as large a body of water as possible acted upon in the direction nearest approaching the vessel's course, without either turns or deflections and this is best to be arrived at—not by any paradoxical form of centrifugal pump, but by the direct action of a screw contained in the water channel; and the same reasoning will apply for similar proposals for aerial propulsion made to this Society. I here assume that the screw is enclosed in an open-ended case; but if there is plenty of clear space in front, the screw will act as well or better without being enclosed; and therefore in spite of the costly experiments that have recently been made to revive the system of jet propulsion, it was clear to him that the screw propeller must be much superior."

J. P. Bourne, who followed, was a well-known member of the Institution of Civil Engineers. He began with the words, "I have read with much interest the first *Annual Report* of your Society for 1866. It has occurred to me that it may be interesting to you to have an account of some experiments made many years ago in South America."

Bourne, in 1843, had been staying with a Dr. Frazer in British Guiana, when the English papers arrived giving an account of Henson's flying machine. Dr. Frazer had always taken a great interest in science, and was also a skilful mechanic. He was convinced that the helicopter was the only method of flying, and Bourne described clockwork models he had made with blades from birds' feathers, models which rose some 20 feet.

E. W. Young, an engineer in the Civil Service, and later a member of the Society's Experimental Committee, during the discussion, put forward a suggestion which was successfully used by Orville and Wilbur Wright thirty years later at Kitty Hawk.

"For trying experiments in the art of flying, the safest would be to fly the aeronaut and his machine on a windy day as you would a kite. Then if the propeller power possessed by the machine were sufficient to slacken the cord by which the machine was held against the wind, the problem would be solved, and Aerial Navigation an accomplished fact."

He confessed, however, his ignorance of aerodynamics to such an extent that it appeared to him that mechanical flight by man was impossible, yet birds flew! He quoted the experimental figures of pressures on flat plates and said, "I suggest the advisability of trying some experiments on the sustaining force of the wind when acting against an inclined surface, for I believe it would be found to be much greater than was commonly supposed."

Wenham, as a member of Council, at once replied that the measuring of the force of the wind in England was almost impracticable, "owing to the diversity of the currents. I propose," he continued, "shortly to try a series of experiments by the aid of an artificial current of air of known strengths, and to place the Society in possession of the results."

Stewart Harrison, proposing a vote of thanks to the Chairman, added "I have no doubt the people outside thought it desirable that those present should be taken care of by their friends. I do not; but I think that, as gentlemen risked something of their reputation for soundness of judgment by taking the Chair when such flighty subjects are discussed, we cannot do less than acknowledge their kindness by a vote of thanks."

At the Council meeting held on 21st August 1867, the following resolution was passed:—

"The Honorary Secretary proposed that an Exhibition of machinery and articles connected with aeronautics should be organised for 1868 and he produced a draft circular which was proposed to be sent to members and friends of the Society to test the possibility of the project, which after some emendations and additions, was adopted and the Secretary was directed to put himself into communication with the Duke of Argyll relevant to the proposed Exhibition."

This was a bold and imaginative proposal on Brearey's part. He made it when the new Society was but a year-and-a-half old, when funds were low and enthusiasm lower still, when he was well aware he was not receiving the support for which he had hoped when he made his suggestion for an aeronautical society in 1865. His proposal was to have a far reaching effect on the Society's reputation and future.

This was the first aeronautical exhibition to be held in the world, and Brearey proposed boldly that it should be held at the famous Crystal Palace, where he was sure it would attract greater attention than anywhere else. He also suggested that particulars of the Exhibition should be sent to enthusiasts in America, Australia and France as well as Great Britain.

On 14th October 1867 he enclosed a circular about the proposal in a letter to John Stringfellow, whom he invited to exhibit. That letter began a friendship which lasted, intermittently, most of Stringfellow's life. In a later letter, when Stringfellow was hesitating to accept, Brearey wrote "It is a great pity that experience like yours should be lost to the world. . . . The Exhibition will take place about the latter end of May or the

beginning of June, which I trust will give you time to complete."

Brearey rarely missed an opportunity to advertise the widespread attention paid to the Society. In May 1867 a Brigadier General E. W. Serrel of New York wrote to the Duke of Sutherland, Vice-President of the Society. The letter was read at the Council meeting and Brearey replied to it, and sent a copy of the correspondence to the *Mechanics Magazine*, in the issue of 24th May 1867. I quote, as it was not given in the Minutes of the Council, and the original letters have been lost.

"My lord," wrote the brigadier, "I have the pleasure of receiving a note from your distinguished countryman William Fairbairn, on the subject of navigating the air, in which he recommends me to address your grace should I desire to know more of the attitude of your Society towards this subject. Having spent considerable time and money investigating the conditions necessary to success in the solution of the problem in question, I have arrived at the conclusion that the thing is attainable by mechanical means, irrespective of any balloons or other equivalents. It has been demonstrated in three trials that the proper direction can be given and maintained; that the elevating force can be sustained where there is sufficient motive power within the recognised limits of weight, and I am now endeavouring to produce the necessary development of power within the prescribed conditions, and this is all, I believe, now wanting to accomplish the result. That is, I find screw propeller fans (of which I have made five, the largest of which are 20 ft. 6 in. in diameter) will lift, with a given shape and pitch of fan, at given velocities, certain weights. . . . I have a machine, built of very light copper, 78 ft. long, with elevators capable of lifting 6 tons, and if it will help to elucidate the question will send you a description and photograph, if your Society will reciprocate by sending me any information you have on the subject I desire, viz. power that is developed by light engines of any kind."

Alas, no photographs nor description appear to have survived in the archives of the Society.

Brearey, who replied on behalf of the Duke of Sutherland, began magnificently by saying, "In the matter of aerial navigation there should not be, and I believe there are not, any national jealousies. The triumph of anyone, whatever his nationality, would be too great a boon to civilisation not to be accepted as a general matter of rejoicing to the whole world, in which the highest and the lowest, the black and the white, would equally participate. While, therefore, it would be a great honour and credit to any individual or body of individuals to solve this long meditated problem, the Aeronautical Society of Great Britain will never withhold from earnest workers in the cause, any information desired in the spirit of your communication which may tend to advance so cosmopolitan an object of desire as locomotion upon an international highway whose termini embrace every dwelling upon earth."

Well, there you are! And here we are, at the moment of writing this, some ninety-five years later, preparing to leave this earth for red faced Mars, or to fly to Venus to see what lies behind her white mantle!

The *Annual Report* paid a tribute to the Council of the Society of Arts for their permission to hold the lecture meetings in their "great room." It is not inopportune here to say that the Aeronautical Society, as many other Societies one suspects, owes a deep debt to the Society of Arts for its encouragement in the lean days of balloonacy and heavier-than-air light-hearted discussions.

At the end of the second year the Aeronautical Society had a total membership of 91, as against 65 for its first year. But much of this membership was financially unproductive. The following year found Brearey reporting many members for not having paid their subscriptions, and ruthlessly asking that they should be expelled from the Society.

Two important additions to the Council were elected during the year, C. W. Siemens, F.R.S., well-known for his work on the telegraph and the dynamo; and W. H. le Feuvre, F.R.G.S., President of the Society of Engineers.

Of all the most astonishing, significant and bold decisions ever made by a Council of the Society, I must commend that one to hold an Aeronautical Exhibition and to press forward regardless of the financial forebodings which so often destroy the visions without which, in the long run, a people perish. Nor was there any wavering in that decision when, at the January 1868 meeting of Council:—

"The Honorary Secretary read the financial statement for the year ending 11th January 1868, by which it appeared that after the payment of all outstanding accounts there was a balance of 13s. 6d. and £29 due from members, including defaulters."

Brearey's cash book records that the balance on 24th February 1868, as audited by Wenham, was actually 3s. 6d.!

Courage, mes enfants of the twentieth century, even if the accountants sit at the Directors' right hands! For where the treasury is, there will it play its part also.

REFERENCES

Annual Report of the Society, 1867; Society's letter files; Council Minutes, 1867; *Mechanics Magazine*, 1867; Patent Specifications.

TECHNICAL NOTE

Flutter of an Aircraft Controlled by an Automatic Navigation System

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1. INTRODUCTION

Automatic navigation systems for aircraft often use gyroscopes to measure the changes in the direction of motion of the aircraft they are controlling. These measurements are fed back to the mechanisms moving the control surfaces of the aircraft.

Such a system is usually designed, in the first instance, assuming the aircraft structure to be rigid and such that the system is then stable.

Now suppose the aircraft structure, considered elastic, is disturbed in flight by, say, a gust. Normal modes of vibration of the structure will be excited, the resulting oscillations will be detected by the gyroscope and fed as error signals to the control surface actuators. If the actuators are capable of following these error signals, the control surfaces will also oscillate, exciting the structure further and so completing the cycle. This cycle may be unstable.

This novel form of flutter is investigated in this note. It is shown that in a system using a fast-reacting modern actuator the danger of this form of flutter is very real.

The existence of instability is demonstrated with a simple mathematical model of an aircraft, the nature of the motion in a limiting case is deduced and some remedies become apparent.

The problem is investigated by the use of Lagrange's Equations of Motion[1] and the Nyquist stability criterion for servo-mechanisms[2]. The calculations may, in practice, be carried out at the same time as a conventional flutter investigation, as the conventional flutter equations form part of the equations derived in this note.

The method is quite general, but is applied here to an elevator system controlling the pitch-plane motion of a simplified aircraft and having a gyroscope feed-back. The theoretical basis of the investigation is explained in some detail, but the numerical work for the aircraft model considered is relegated to Appendix I.

2. THE CONTROL LOOP

The control loop is shown diagrammatically in Fig. 1.

When the navigation system requires the aircraft to change direction in the pitch-plane it calls for a pitch rate, q. This pitch rate is measured by a gyroscope placed at some point in the aircraft. The pitch rate is subtracted from the original demanded pitch rate and the difference or "error" is fed to the elevator actuator, which may be some form of hydraulic jack.

3. THE NYQUIST CRITERION IN THIS PROBLEM

To investigate the stability of such a system it is necessary to examine the underlying differential equations. These differential equations are either shown or assumed to be expressible as polynomials in the operator $D \equiv d/dt$, with constant coefficients.

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The elevator actuator is assumed to produce an angle of incidence β, relative to a nearby datum line fixed in the aircraft body given by

$$F_1(D)\,\beta = G_1(D)\,\varepsilon \qquad . \quad . \quad (1)$$

where ε is the pitch rate error. This equation governs the so called "open-loop" response of the actuator. If the actuator is to be stable, equation (1) must have stable transients, that is solutions of

$$F_1(D)\,\beta = 0 \qquad . \quad . \quad (2)$$

which, in general, are of the form $\beta = Ae^{(r+is)t}$ where $i = \sqrt{-1}$, and r and s are real, must have $r < 0$ so that the solutions tend to zero as $t \to \infty$. We may allow, in addition, a solution with $r = s = 0$.

In practice the functions $F_1(D)$ and $G_1(D)$ may not be known explicitly, but the steady state response of β to a steady sinusoidal ε input to an actuator may be found experimentally for varying frequencies. This enables a locus to be drawn on the Argand diagram of

$$\frac{G_1(i\omega)}{F_1(i\omega)}$$ for varying ω, ω being the frequency of the input.

This locus and the knowledge that the "open-loop" actuator is stable are sufficient for our purpose.

The relation between the elevator incidence, β, and the pitch rate at the gyroscope position, q, is shown later in this note to be of similar form,

$$i.e.\ F_2(D)\,q = G_2(D)\,\beta \qquad . \quad . \quad (3)$$

The transients of this equation, that is solutions of

$$F_2(D)\,q = 0 \qquad . \quad . \quad (4)$$

must also be stable, for, if not, then the aircraft will flutter in the conventional sense[7], with zero β elevator-body angle.

We now consider the open loop of the control system, from the pitch rate error, ε, to the pitch rate, q, produced at the gyroscope. From equations (1) and (3) we have[3]

$$F_1(D)\,F_2(D)\,q = G_1(D)\,G_2(D)\,\varepsilon. \qquad . \quad . \quad (5)$$

If the two parts of the loop that we have discussed are stable, then the combined open loop represented by equation (5) will be stable.

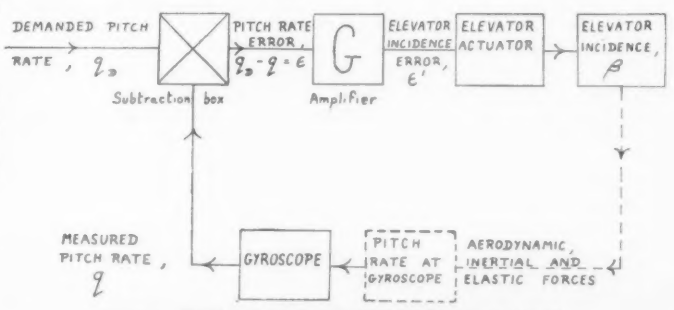


FIGURE 1. Pitch control loop using gyroscope feed-back.

We are interested, however, in the stability of the loop when it is closed through the subtraction box. The error then becomes $q_D - q$, where q_D is the demanded pitch rate and q the measured pitch rate (which is assumed in this note to be equal to the actual pitch rate at the position of the gyroscope, which thus measures accurately both in amplitude and phase).

The closed loop equation, substituting $\varepsilon = q_D - q$ in equation (5) is

$$[F_1(D)\,F_2(D) + G_1(D)\,G_2(D)]\,q = G_1(D)\,G_2(D)\,q_D. \quad (6)$$

The stability of this loop depends on the solution of

$$[F_1(D)\,F_2(D) + G_1(D)\,G_2(D)]\,q = 0 \quad . \quad (7)$$

If the functions $F_1(D)$, $F_2(D)$, $G_1(D)$ and $G_2(D)$ were all real and known explicitly then the Routh[4] or Hurwitz[5] stability criteria could be applied to the coefficients of the powers of D. However, even if $\frac{G_1(i\omega)}{F_1(i\omega)}$ and $\frac{G_2(i\omega)}{F_2(i\omega)}$ only are known, the stability of equation (6) may still be determined by using the well known Nyquist criterion[2], which is explained below.

In the language of the Complex Integral Calculus equation (7) will have stable transients if the function

$$F_1(z)\,F_2(z) + G_1(z)\,G_2(z)$$

has no zeros in the half plane $R(z) \geqslant 0$, $R(z)$ being the real part of z. The same is true of the function

$$\phi(z) \equiv 1 + \frac{G_1(z)\,G_2(z)}{F_1(z)\,F_2(z)}.$$

Now in $R(z) \geqslant 0$, $F_1(z)$ has no zeros, except possibly at $z=0$, and $F_2(z)$ has no zeros at all, so $\phi(z)$ has no infinities or "poles," except possibly at $z=0$. By applying a well known contour integration theorem[6] it may be shown that a condition that $1 + \frac{G_1(z)\,G_2(z)}{F_1(z)\,F_2(z)}$ has no zeros for $R(z) \geqslant 0$ is that the locus of $1 + \frac{G_1(i\omega)\,G_2(i\omega)}{F_1(i\omega)\,F_2(i\omega)}$ must not encircle the origin as ω varies from $+\infty$ to $-\infty$, with suitable allowances for the behaviour of the locus as $\omega \to 0$ and $\omega \to \infty$. It is only necessary to consider the locus from $\omega = 0$ to $+\infty$ as the rest of the locus is the mirror image of the first part in the real axis.

The condition above may be restated in the traditional form of the Nyquist criterion[2] that the locus of $\frac{G_1(i\omega)\,G_2(i\omega)}{F_1(i\omega)\,F_2(i\omega)}$ must not encircle the point $(-1, 0)$.

Examples of loci for stable and unstable loops are shown in Fig. 2. The form of the locus as $\omega \to 0$ and $\omega \to \infty$ merits attention. This is derived from the contour used when applying theorem mentioned above: in practice the locus tends to infinity as $\omega \to 0$ and may be considered completed by a large semi-circle or circle from $\omega = +0$ to $\omega = -0$ running in an anti-clockwise direction. (Such circles are shown in Fig. 2.) The locus usually tends to the origin as $\omega \to \infty$.

Now $\frac{G_1(i\omega)\,G_2(i\omega)}{F_1(i\omega)\,F_2(i\omega)}$ is the product of the open loop response of the elevator actuator and the response in ω at the gyroscope to a sinusoidal oscillation, β, of the elevators. $\frac{G_1(i\omega)}{F_1(i\omega)}$ may be determined experimentally, and the derivation of $\frac{G_2(i\omega)}{F_2(i\omega)}$ is now discussed.

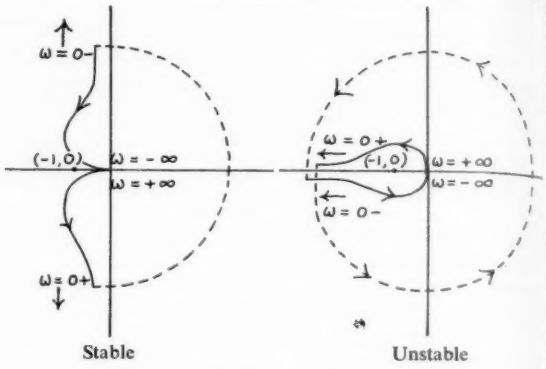


FIGURE 2. Examples of the Nyquist criterion.

4. THE AIRCRAFT RESPONSE

Figure 3 illustrates the mathematical aircraft model considered. To derive the equations of motion for the aircraft when excited by a steady oscillating elevator-body angle (from which $G_2(i\omega)/F_2(i\omega)$ will be found) a system of generalised co-ordinates may be set up as in Fig. 4. The body is considered as a number of discrete masses, m_i, and the position of the ith mass is defined by a bending displacement y_i, relative to a datum line fixed in the body, a pitching angle of this line, q_2, and a translation of this line, q_1. The kinetic energy, required for Lagrange's Equations[1], may then be written:

$$T = \frac{1}{2} \sum_i m_i (\dot{q}_1 + x_i \dot{q}_2 + \dot{y}_i)^2. \quad . \quad . \quad (8)$$

It is possible to obtain the equations of motion in terms of these co-ordinates and β, but in practice the equations would be large in number and cumbersome to handle, even with an electronic digital computer.

To investigate the effect of body bending it is convenient, therefore, to restrict the degrees of freedom to three co-ordinates, q_1, q_2 as before, and q_3 as illustrated in Fig. 5. This is the familiar assumption of "semi-rigidity."

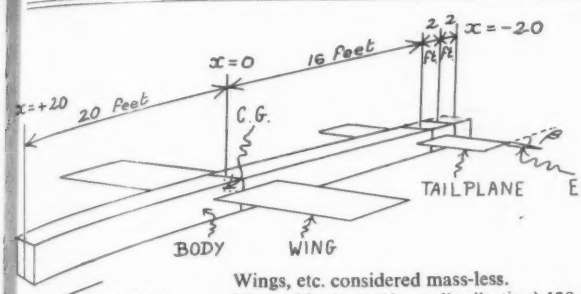
The body bending mode represented by q_3 is the fundamental free-free vibration mode of the body in vacuo. This is shown in Fig. 6. The mass distribution of the body is uniform, and the stiffness distribution is supposed to be such that the quadratic curve of Fig. 6 represents the fundamental vibration mode having a frequency of 100 radians sec.$^{-1}$.

The resulting equations of motion can therefore be considered fully valid only for frequencies, ω, of β in the neighbourhood of the fundamental body frequency. (At low frequencies there will be body distortion, but not necessarily in the body free-free mode assumed. One method of calculating the aeroelastic effect at these frequencies is to use the q_1 and q_2 freedoms only, but to modify the q_1, q_2 and β aerodynamic forces for distortion in steady state manoeuvres.)

With these simplifications the kinetic energy becomes

$$T = \frac{1}{2} M \dot{q}_1^2 + \frac{1}{2} I \dot{q}_2^2 + \frac{1}{2} \frac{M}{5} \dot{q}_3^2.$$

In practice additional degrees of freedom such as wing bending might have to be taken into account, and the mass and stiffness distributions will be far from uniform.



Wings, etc. considered mass-less.
Mass of body (uniform distribution) 120 slugs.
Pitch-plane moment of inertia about c.g. 16,000 slugs ft.².

Aerodynamics:	Lift coefficient $\frac{S}{}\frac{\partial C_L}{\partial \alpha}$		c.p. position	
Wings	200	ft.² per radian	$x=0$	ft.
Tailplanes	20		$x=-16$	
Elevators	20		$x=-18$	

FIGURE 3. Mathematical model of aircraft.

The potential energy, stored in the bent body, is also required for Lagrange's equations and is arranged to give the correct frequency for the vibration when q_3 motion only is allowed. In this example:—

$$V=\frac{1}{2}\frac{M}{5}\lambda^2 q_3^2 \text{ where } \lambda=10^2 \text{ rad. sec.}^{-1}.$$

Structural or "hysteretic" damping has been included in the calculation by multiplying V by $(1+ig)$, where g is the structural damping coefficient and is taken as 0·04.

The lift coefficients for the wings, tail planes and elevators are shown in Fig. 3. "Quasi-steady" aerodynamics have been used for simplicity. Thus the lift on the wing has been taken as

$$L_1=\frac{1}{2}\rho V_A^2 \times S\frac{\partial C_L}{\partial \alpha}\left\{\frac{q_2-[\dot{q}_1-0{\cdot}5\dot{q}_3]}{V_A}\right\} \text{ lb.}$$

acting at $x=0$.

The q_2 term represents the force resulting from the incidence of the wing, but as $\dot{q}_1-0{\cdot}5\,\dot{q}_3$ is its vertical motion this incidence will be diminished by a small angle $\frac{\dot{q}_1-0{\cdot}5\,\dot{q}_3}{V_A}$ radians, where V_A is the forward velocity of the aircraft. In the calculations, (Appendix I)

$\frac{1}{2}\rho V_A^2=6{,}000$ lb. ft.$^{-2}$; $V_A=2{,}250$ ft. sec.$^{-1}$.

In practice the aerodynamic forces would be obtained making use of appropriate flutter derivatives for the wings, tail planes, elevators and body (all these are oscillating sinusoidally under the action of β).

Lagrange's equations of motion[1] are

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right)+\frac{\partial V}{\partial q_i}=Q_i \ (i=1,2,3) \quad . \quad (9)$$

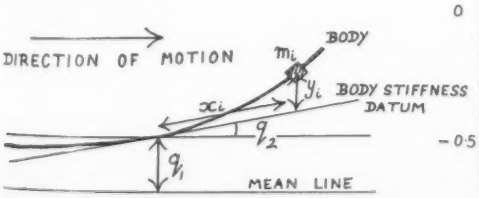


FIGURE 4. Generalised co-ordinates q_1, q_2, y_i.

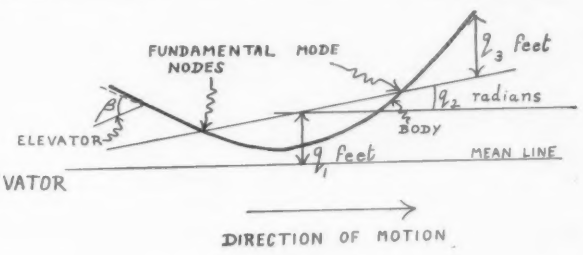


FIGURE 5. Co-ordinates q_1, q_2, q_3, β.

T and V have already been found and the Q_i, the generalised forces, may be found easily in terms of the aerodynamic forces. Q_1, for example, is defined as follows: if in a displacement δq_1 of q_1, δW work is done by the aerodynamic forces, then $Q_1=\delta W/\delta q_1$.

With the model under discussion the Lagrange equations[1] are

$$\left.\begin{aligned} M\ddot{q}_1 &= Q_1 \\ I\ddot{q}_2 &= Q_2 \\ \frac{M}{5}\ddot{q}_3+\frac{M}{5}\lambda^2(1+ig)q_3 &= Q_3 \end{aligned}\right\} \quad . \quad . \quad (10)$$

The Q_i are linear functions of q_1, q_2, q_3, β and their time derivatives. Q_1, for example, is given by

$$Q_1=1{,}440{,}000\,q_2-28{,}800\,q_3+120{,}000\beta$$
$$+53{\cdot}333\dot{\beta}-640\,\dot{q}_1+1813{\cdot}333\,\dot{q}_2+204{\cdot}8\,\dot{q}_3.$$

Replacing $\dot{q}_1$ by $i\omega q_1$ etc. for a steady oscillatory solution we may write the equations in the form

$$\mathbf{(A)}\ \{\mathbf{q}\}=\{\mathbf{b}\} \quad . \quad . \quad . \quad (11)$$

where **(A)** is a 3×3 matrix whose elements are polynomials of degree 2 in ω with complex coefficients, $\{\mathbf{q}\}$ is the column vector $\begin{pmatrix} q_1 \\ q_2 \\ q_3 \end{pmatrix}$, $\{\mathbf{b}\}$ is a column vector of three complex numbers involving ω, and β is the modulus of the control surface-body angle, oscillating at frequency ω rads. sec.$^{-1}$. These equations are written in full in Appendix I.

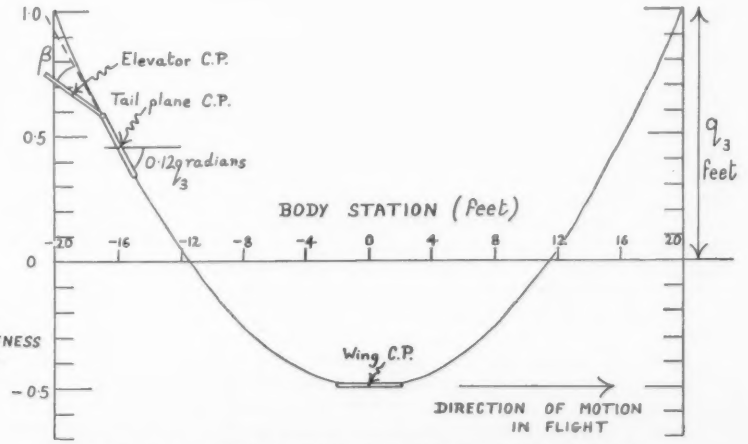


FIGURE 6. Body bending mode in vacuo, frequency 100 rad. sec.$^{-1}$.

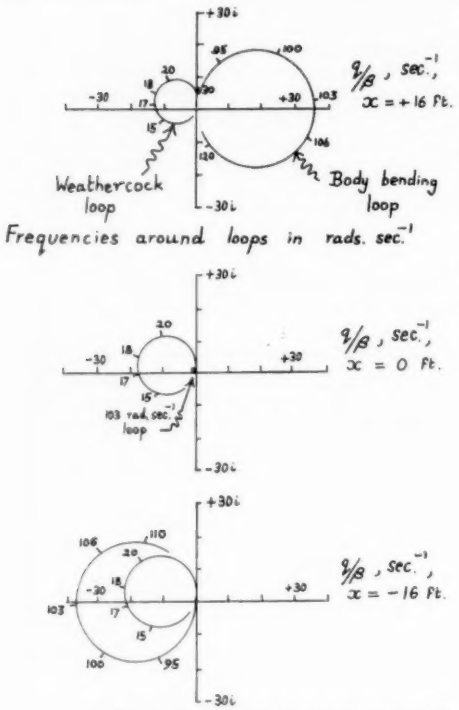


FIGURE 7. Pitch rate at gyroscope, q/β.

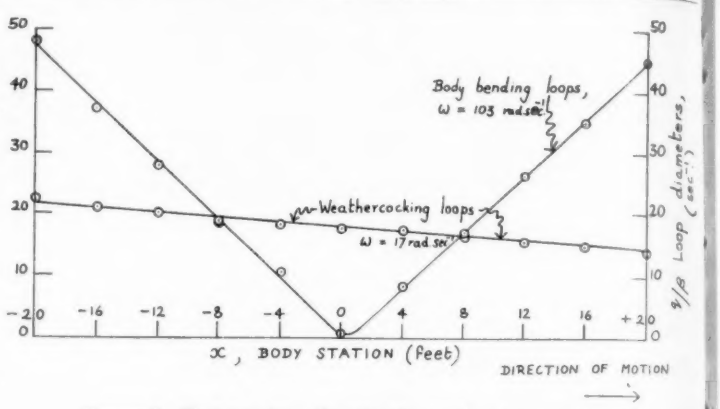


FIGURE 8. Pitch rate loop diameters for varying gyroscope position.

We may solve for q_2/β, q_3/β in terms of ω and so obtain the pitch rate q at a point x as

$$\frac{q}{\beta} = i\omega \left\{ \frac{q_2}{\beta} + f'(x) \frac{q_3}{\beta} \right\} . \quad . \quad . \quad (12)$$

$f'(x)$ being the gradient of the body bending mode, or the additional local pitch due to body bending. A digital computer programme for this work is available[8].
(A) $\{\mathbf{q}\} = \{\mathbf{0}\}$ is the conventional flutter equation[7] in these degrees of freedom (with $V_A = 2{,}250$ ft. sec.$^{-1}$).

Equation (12) may be expressed in the form

$$\frac{q}{\beta} = \frac{G_2(i\omega)}{F_2(i\omega)} \quad . \quad . \quad . \quad (13)$$

and plotted on the Argand diagram for various gyroscope positions, x. Fig. 7 shows plots, for varying ω, for gyroscopes at $x = +16$, 0 and -16 ft.

The transients obtained from (A) $\{\mathbf{q}\} = \{\mathbf{0}\}$ are stable and so $F_2(z)$ has no zeros in the half plane $R(z) \geqslant 0$.

Each locus has two circular loops. These correspond to resonances due to weathercocking and body bending of the aircraft. The weathercocking motion of the rigid aircraft has a frequency of about 17 rads. sec.$^{-1}$. This motion is the oscillation of the aircraft under the restoring action of the aerodynamic forces on its wings and tail planes when disturbed from its path. The motion may be found by solving the first two Lagrange equations, omitting damping terms and with $\beta = 0$. In this motion a point 47 ft. forward of the centre of gravity remains stationary.

The q/β locus may be plotted for varying values of x and the diameters of the resulting loops plotted against x as in Fig. 8. Notice that the loop due to weathercocking is nearly constant with x, showing that there is only a small amount of body bending present in the solution.

The q/β loop for β excitation frequencies of about 103 rads. sec.$^{-1}$ has a minimum at $x = 0$, the antinode of the body bending mode, but does not vanish at this point. This body bending loop diameter increases linearly with $|x|$ for $0 < |x| < 20$, as does the modulus of the gradient of the body bending mode $|3x/l^2|$.

5. ACTUATOR RESPONSE AND CLOSED LOOP STABILITY

Figure 9 shows the open-loop response of a modern actuator. This is a plot of

$$\frac{\beta}{\varepsilon'} = \frac{G_1'(i\omega)}{F_1'(i\omega)} \text{ , where } \varepsilon'$$

is the error signal measured in radians. It includes some "phase advance" at 17 rads. sec.$^{-1}$ to avoid instability in the weathercock motion.

This actuator at very low frequencies acts as an integrator that is $\beta \propto \varepsilon'$. $\dfrac{G_1'(z)}{F_1'(z)}$ has a single pole at the origin. In this example it is assumed that the actuator response is not significantly affected by the external forces and moments. This is true of powerful hydraulic mechanisms. (If this were not the case then to apply this method it would be necessary to devise a linearised relationship between ε', q_1, q_2, q_3 and β to represent the actuator response and combine this with equations (10) to give a 4×4 matrix connecting q_1, q_2, q_3, β with ε'. The analysis would then be completed in a similar way to what follows.)

Now $\dfrac{G_1(i\omega)}{F_1(i\omega)} = \dfrac{\beta}{\varepsilon}$ where ε is pitch rate error in rads. sec.$^{-1}$.

The control loop of Fig. 1 contains a box "G" to make this conversion. This amplifies the demand so that

$$\varepsilon' = -0{\cdot}45\ \varepsilon.$$

The amplifying factor is $-0{\cdot}45$ rads./rad. sec.$^{-1}$. The larger numerically this amplifying factor is the more quickly the system will respond to a demand. The object is to make it as large as possible without setting up instability. The loop may, of course, be designed to meet more sophisticated criteria such as optimum performance in the presence of noise. This is beyond the scope of this note which considers possible aeroelastic instabilities.

Hence $\dfrac{G_1(i\omega)}{F_1(i\omega)} = \dfrac{\beta}{\varepsilon} = \dfrac{G_1'(i\omega)}{F_1'(i\omega)} \times \dfrac{\varepsilon'}{\varepsilon} = -0{\cdot}45\ \dfrac{G_1'(i\omega)}{F_1'(i\omega)}$

and the open loop response of the complete system, from a demanded q_D to the measured q, is given by

$$\frac{q}{q_D} = -0{\cdot}45\,\frac{G_1'(i\omega)}{F_1'(i\omega)} \times \frac{G_2(i\omega)}{F_2(i\omega)} \quad . \quad . \quad (14)$$

q/q_D is plotted in Fig. 10 for the gyroscope positions at $x=+16$ ft., $x=0$ and $x=-16$ ft. Below 10 rads. sec.$^{-1}$ the loci tend along the negative imaginary axis under the influence of $\frac{G_1'(i\omega)}{F_1'(i\omega)}$ and are completed by an infinite semi-circle in the right hand half plane. Applying the Nyquist criterion[2] explained earlier it will be seen that both the $x+16$ ft. position and $x=-16$ ft. position result in closed loop instability, caused by the presence of the body bending loop. For $x=0$ however we obtain stability. For some gyroscope position between $x=0$ and $x=-16$ ft., say, with a closed loop, a steady oscillation will be produced. The nature of this motion and approximate phase relationships are shown in Fig. 11. In this sequence $q_D=0$.

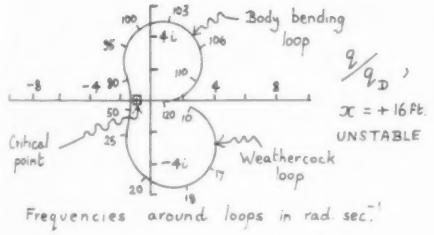
In the position numbered 90° the aircraft imagines it is going in a downward circle (negative pitch rate at the gyroscope). It therefore demands negative β to correct this. β is lagging some 120° behind the demand. Thus the full β angle is attained later, and the β force does positive work during the cycle, balancing the energy lost through structural and aerodynamic damping.

6. DISCUSSION

A new type of flutter involving the pitch-control loop this simplified aircraft has thus been demonstrated.

Cures which suggest themselves are:—

(*i*) siting the gyroscope near an antinode of the troublesome mode: in practice, however, there may be more than one such mode;



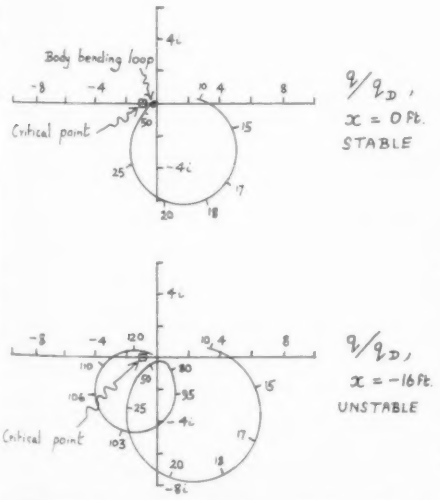


FIGURE 10. q/q_D loci for $x=+16, 0, -16$ ft.

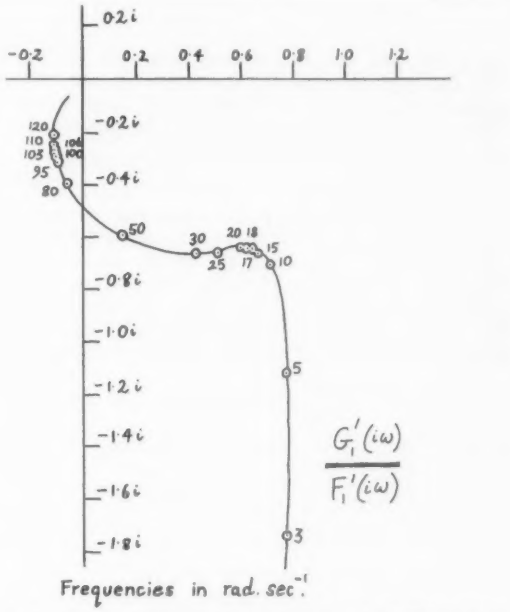


FIGURE 9. Open loop actuator response, including phase advance at 17 rad. sec.$^{-1}$.

(*ii*) reducing the amplification factor (−0·45): this is undesirable as it slows up the response of the system;

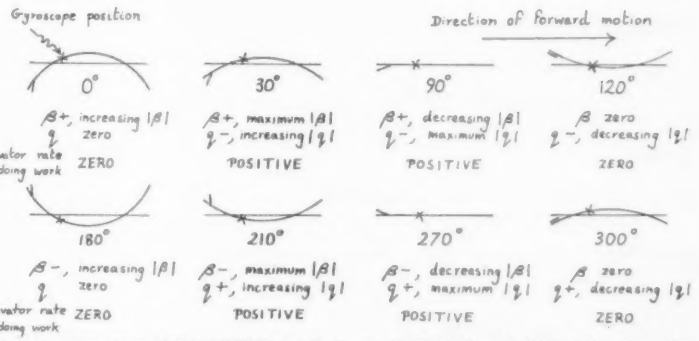
(*iii*) inserting electrical means of altering phases or amplitudes in the loop at the critical frequencies only. This would have the effect of moving the troublesome loops in Fig. 10 clear of the critical point, or reducing the loop sizes;

(*iv*) stiffening the structure to raise the frequencies of the troublesome modes above those at which the actuator is effective. This has an undesirable weight penalty;

(*v*) using a slower reacting actuator. This suffers the same disadvantage of (*ii*).

Methods (*i*) and (*iii*) appear to be the most promising.

Clearly an analysis of this type will have to be undertaken in addition to conventional flutter analysis, whenever it is proposed to fit an automatic navigation system with similar feed-back to an aircraft and to use an actuator which has an appreciable response at the lower structural resonant frequencies. Similar analyses may have to be



(The elevator does NEGATIVE work from 120°-180° and 300°-360°, but the total work done in the cycle is POSITIVE)

FIGURE 11. Nature of the motion for critical gyroscope position. (β=elevator angle relative to body; q=apparent pitch rate at gyroscope position.)

made for yaw and roll control loops. It is emphasised that the type of instability demonstrated can arise in an aircraft which is free of flutter in the conventional sense. This phenomenon has been recently mentioned[9] with reference to the Black Knight rocket.

7. ACKNOWLEDGMENTS

The author would like to acknowledge the earlier work on this problem by his former colleagues in Bristol Aircraft Ltd., Mr. S. A. Smith and Mr. M. H. Butterfield, and to thank the following:— Mr. D. J. Farrar, F.R.Ae.S., for advice in preparing the text, Mr. F. G. Duncan, who did the matrix work on a DEUCE computer and Miss E. A. Coakley who did much for the preparatory computing work.

APPENDIX I

The body bending mode is given by

$$f(x)=\frac{3x^2-l^2}{2l^2} \text{ where } l=20 \text{ ft.}$$

$$2T=\int_{-l}^{+l} m\,(\dot{q}_1+x\dot{q}_2+f(x)\,\dot{q}_3)^2\,dx$$

where $m=3$ slugs ft.$^{-1}$, the line density of the body.

Whence $2T=M\dot{q}_1^2+I\dot{q}_2^2+(M/5)\,\dot{q}_3^2$

where $M=120$ slugs, $I=16{,}000$ slugs ft.^{2}

$$2V=(M/5)\,\lambda^2 q_3^2\,(1+ig)$$

where $\lambda=100$ rads. sec.$^{-1}$, $g=0{\cdot}04$.

The aerodynamic forces are

$$L_1=6000\times 200\times\left(q_2-\frac{[\dot{q}_1-0{\cdot}5\dot{q}_3]}{2250}\right) \text{ lb.}$$

on the wings at $x=0$.

$$L_2=6000\times 20\left(q_2-0{\cdot}12q_3-\frac{[\dot{q}_1+0{\cdot}46\dot{q}_3-16\dot{q}_2]}{2250}\right) \text{ lb.}$$

on the tailplanes at $x=-16$ ft.

$$L_3=6000\times 20\left(q_2-0{\cdot}12q_3+\beta-\frac{-[\dot{q}_1+(0{\cdot}46+2\times 0{\cdot}12)\,\dot{q}_3-1{\cdot}0\times\beta-18\dot{q}_2]}{2250}\right) \text{ lb.}$$

on the elevators at $x=-18$ ft.

The generalised forces are

$$Q_1=L_1+L_2+L_3$$

$$Q_2=0\times L_1-16\times L_2-18\times L_3$$

$$Q_3=-0{\cdot}5L_1+0{\cdot}46L_2+0{\cdot}70L_3$$

whence

$$Q_1=1{,}440{,}000q_2-28{,}800q_3+120{,}000\beta+ +53{\cdot}333i\omega\beta-640i\omega q_1+1813{\cdot}333i\omega q_2+204{\cdot}8i\omega q_3$$

$$Q_2=-4{,}080{,}000q_2+489{,}600q_3-2{,}160{,}000\beta-960i\omega\beta+ +1{,}813{\cdot}333i\omega q_1-30{,}933{\cdot}33i\omega q_2+1064{\cdot}533i\omega q_3$$

$$Q_3=-460{,}800q_2-16{,}704q_3+84{,}000\beta+ +37{\cdot}333i\omega\beta+204{\cdot}8i\omega q_1+1064{\cdot}533i\omega q_2-170{\cdot}752i\omega q_3$$

writing $i\omega q_1$ for $\dot{q}_1$ etc.

Lagrange's equations $\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right)+\frac{\partial V}{\partial q_i}=Q_i\ (i=1,2,3)$

may be written in matrix form:

$$\begin{pmatrix} -120\omega^2 & -1{,}440{,}000 & +28{,}800 \\ +640i\omega & -1{,}813{\cdot}333i\omega & -204{\cdot}8i\omega \\ \hline & +4{,}080{,}000 & -489{,}600 \\ -1{,}813{\cdot}333i\omega & +30{,}933{\cdot}333i\omega & -1064{\cdot}533i\omega \\ & -16{,}000\omega^2 & \\ \hline & +460{,}800 & +256{,}704 \\ -204{\cdot}8i\omega & -1064{\cdot}533i\omega & +170{\cdot}752i\omega \\ & & -24\omega^2 \\ & & +9{,}600i \end{pmatrix} \begin{pmatrix} q_1 \\ \hline q_2 \\ \hline q_3 \end{pmatrix}$$

$$= \begin{pmatrix} 120{,}000 \\ +53{\cdot}333i\omega \\ \hline -2{,}160{,}000 \\ -960i\omega \\ \hline 84{,}000 \\ +37{\cdot}333i\omega \end{pmatrix} \beta$$

Hence q_2/β, q_3/β may be found as functions of ω, and also

$$\frac{G_2(i\omega)}{F_2(i\omega)}=\frac{q}{\beta}=i\omega\left(\frac{q_2}{\beta}+f'(x)\,\frac{q_3}{\beta}\right),$$

where $f'(x)=6x/(2l^2)$.

The actuator open loop response plotted in Fig. 8 is assumed to be

$$\frac{G_1'(i\omega)}{F_1'(i\omega)}\equiv\left(\frac{a_0}{a_1 i\omega+a_2(i\omega)^2}\right)\times\left(\frac{0{\cdot}1+0{\cdot}0186i\omega}{1+0{\cdot}0186i\omega}\right)$$

where $a_0=500$, $a_1=10$, $a_2=0{\cdot}1$.

The second bracket represents the phase advance for 17 rads. sec.$^{-1}$

and $$\frac{G_1(i\omega)}{F_1(i\omega)}=-0{\cdot}45\,\frac{G_1'(i\omega)}{F_1'(i\omega)}.$$

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Following on an exception to honour the 10th anniversary of the Chester Branch, we revert to historical sequence with the formation of the DERBY Branch in 1944.

With distinctive headgear and racehorses, in themselves symbols of the best, the name of DERBY is obviously linked with that other symbol of elegance—Rolls-Royce. In the aviation side of the business, the symbol of the bird of prey has been very evident since the First World War. The symbol of the rivers came at the end of the last war, and with this long association with British and World aviation it is perhaps surprising that a Derby Branch of the Royal Aeronautical Society was not formed until 1944. But here the story begins—

In January 1944, 19 members of the Royal Aeronautical Society living in and around Derby, attended a meeting under the chairmanship of Mr. A. G. Elliott, at which a formal resolution was passed stating that it was ". . . desired to form a Branch of the Society in Derby . . ."

At a further meeting in March, a letter was read formally approving formation of the Derby Branch. The position of Mr. A. G. Elliott as Chairman was confirmed, and Mr. J. L. Batchelor was elected Honorary Secretary. Lord Hives accepted the invitation to be President of the Branch.

With a membership at this time of 347, the inaugural lecture was given by Mr. P. G. Masefield in May, his subject being "American Aircraft."

There is some note of prophecy in this first lecture, in that the first Chairman of Beagle is now producing a rival to "American Aircraft," and Rolls-Royce are to produce an American engine.

The Derby Branch has always been virile and enjoys good support for its activities. Membership has fluctuated over the years, but for some time now has been steady at around 300, two-thirds of these being also Royal Aeronautical Society members. Average attendance at lectures is about 80, but it is not at all unusual to have attendances of well over 100. On one memorable occasion, in April 1957, when Mr. A. Curran lectured on the Boeing 707, the attendance was over 400—Rolls-Royce engines, of course.

As hinted, the main source of membership has been from Rolls-Royce, and the Branch has excellent support from the Company in carrying on its activities. Lectures are held in the Rolls-Royce Welfare Hall at Nightingale Road.

The present Chairman is Mr. A. A. Rubbra, who succeeded Mr. A. G. Elliott in 1956, and Mr. J. D. Pearson succeeded Lord Hives as President in 1957.

There have been five Hon. Secretaries, whose names are recorded for their services to the Branch:—Mr. J. L. Batchelor (1944-1950); Mr. C. Ainsworth Davies (1950-1951); Mr. C. L. Hinings (1951-1953); Mr. W. R. Bendall (1953-1959); Mr. J. H. Stephens, the present Secretary, succeeded Mr. Bendall in March 1959.

The major Branch occasion of the year is the Sir Henry Royce Memorial Lecture, which was founded in 1956. The President of the Royal Aeronautical Society has twice honoured the occasion with his presence and every year a large number of distinguished persons from all branches of the Industry accept invitations to attend. The occasion is rendered the more memorable by a dinner given by the Directors of Rolls-Royce Limited.

As befits its support, the Branch has been primarily interested in the propulsion aspects of aeronautics and the Committee has always urged that due prominence should be given to these matters in the Society's Proceedings. In order to further this, in 1957 the Council of the Royal Aeronautical Society agreed to alter the terms of the Akroyd Stuart Prize award to apply specifically to publications on Aircraft Propulsion. It was also agreed that lectures on propulsion matters would be given more prominence in the JOURNAL, as suitable papers became available.

As a further attempt to stimulate interest in propulsion matters, the Branch tried a rather out of the ordinary venture (for a Branch) in March 1958. A Propulsion Symposium was held, two papers being presented in an afternoon, and two in an evening session. The occasion was well attended by members of the aero-engine industry and adjudged successful. Derby hope to repeat this type of function in the not too distant future.

The Branch has good relations with the Derby Centre of the Automobile Division of the Institution of Mechanical Engineers and a joint lecture is a feature of the annual programme. Also held every year is a 10-minute paper competition for Branch members only, which has been very successful in recent years and produced one winner of the N. E. Rowe medal award. In this context, we record that past and present members of the Branch have received awards and prizes ranging from the Society's Gold Medal to the N. E. Rowe prize.

Committee members are also active in the affairs of the main Society. Mr. A. A. Rubbra and Mr. A. V. Cleaver are both Members of Council, the latter also being Chairman of the Astronautics and Guided Flight Section, and the previous Secretary, Mr. Bendall, was for many years an active member of the Branches Committee.

In response to a recent suggestion of the Councils of the Institution of Electrical Engineers and the Royal Aeronautical Society, the Branch is joining with the East Midlands Branch of the Institution of Electrical Engineers and the Leicester Branch of the Royal Aeronautical Society to hold lectures on the applications of electrical engineering in aircraft. The first joint lecture is to be held at Loughborough on 9th May, when Mr. M. Hancock, Head of the Electrical Engineering Department, R.A.E., will speak on "New Ideas in Aircraft Electrical Systems."

Almost to the month, Derby has completed 17 years, which time has seen astonishing changes in aviation and in aircraft propulsion. The pace is accelerating and with an assured future, may we persist in the symbolic with "Hats off" to the Derby Branch.

N. E. Rowe Medals Competition

The Branches Committee have now made their recommendations on the 1960 winners of the 21-26 and under 21 years groups, and names will be announced elsewhere.

Branches Conference

At the invitation of the Preston Branch, the 1961 Spring Conference is to be held on Saturday 13th May, at the Majestic Hotel, St. Annes-on-Sea. A résumé of the Conference will be given on the Branches Page in the June JOURNAL.

Branch Histories

For future reference, will Branch Secretaries please note the planned publication in the JOURNAL:—

May—Luton.
June—Branches Conference.
July—Birmingham and Wolverhampton.
August—Glasgow.
September—Leicester.
October—Reading.
November—Preston.
December—Halton.

Main Lecture at the Chester Branch

Following hard on their tenth anniversary, a most successful and well attended Main Society lecture was given at Chester on "Low Speed Problems of High Speed Aircraft"; support came from several Branches and from the Society's President, Dr. Moult, and the Secretary, Dr. Ballantyne. Your scribe was honoured to be invited (not as a member of the Branches Committee, but as representing Bristol! His regrettable absence from the previous Bristol Barnwell Memorial Lecture suggests another lecture on "High Speed Problems of Low Speed Aircraft").—G.W.-W.

Graduates' and Students' Section

Comments on the Section Annual General Meeting, 1961

The past year has been a time of great change for the Royal Aeronautical Society, culminating in the opening of the new Lecture Theatre, and as might be expected reverberations have been felt in the Graduates' and Students' Section.

It was apparent during the early part of the Annual General Meeting of the Section, held on 1st March, that a change in procedure meant that the customary exciting tussle for election to the Committee would not take place—exciting that is to the candidates, since they were usually attempting to avoid election! Instead, postal applications had to be made for nomination and since only three were received to fill the three positions vacated by the retiring members, it was possible to dispense with the postal ballot and duly elect the only nominees. It was a source of disappointment to the Committee that no further nominations were received; it being felt, with some justification, that from the thousand or more students and graduates in the London area it should have been possible to find more than three members willing to spend a little of their time and energy assisting the operation of their own Section.

This general lack of interest in the Section displayed by most graduates and students was emphasised by the Chairman in his Report to the Council, regarding the very poor attendance figures for lectures, although this may have been affected by the unavoidable choice of unsuitable dates, due to the construction of the Lecture Theatre. It is to be hoped that this latter difficulty will be non-existent in the coming year.

The few Social Activities organised by the Section, however, appear to have been regarded with approval by members, and the Dance was well attended. Unfortunately, on that occasion the liquid refreshment supply was not equal to the demand. This state of affairs will be remedied in future, but as the Chairman pointed out financial planning is precarious and if the number of tickets sold is merely a dozen below the estimate, a heavy loss is incurred. The next dance should be held in the Lecture Theatre, and the Committee hopes to make it a gala occasion.

Many interesting new avenues are being explored by the Committee. One of the most promising, particularly to those who have not yet graduated, is a series of small informal visits to the Royal Aircraft Establishment at Farnborough. These visits, to discuss such specialist subjects as cannot be adequately covered in a general visit, should be of the utmost value to those students who wish to obtain some idea of what research work is really like, or who may be preparing to concentrate on a particular line of study perhaps with a view to producing a thesis. Since the numbers involved are small—about half a dozen—this would seem to be an invaluable opportunity to tackle the expert in person on his home ground. If successful, it is hoped to extend the scheme to cover other Establishments.

Looking further into the future, the liaison established between the Section and the Students' Section of the American Institute of the Aerospace Sciences may well bear further fruit, and it is not beyond the bounds of possibility that something akin to a minor version of the Anglo-American Conference might be arranged.

The Committee is not neglecting its contacts with the other Engineering Institutions at home, however, and attempts are currently being made to foster relationships by arranging a cricket match against the Institution of Mechanical Engineers.

Another project which is on the verge of completion is the publication of a Careers Booklet, being concerned with introducing Industry to the school-leaver. This booklet has involved a great deal of effort and it is hoped that it will appear this year.

One further scheme deserves attention. It may not be generally realised that attractive prizes await the student or graduate who is disposed to prepare and submit a paper to the Society. Details of these internal prizes—and others of a more general and external nature—will eventually be published in the JOURNAL, and members are encouraged to take advantage of this facility.

The coming year will see another visit to the Paris Aero Show and this popular and relatively inexpensive visit shows every indication of becoming a regular fixture in the Section programme.

In conclusion, the Committee appeals to the graduates and students of the Society to play an active part in the running of their Section. The Editor of the Section welcomes letters or postcards containing suggestions for visits, lectures, lecturers, and views on the state of the Industry or such relevant topics. There are three thousand Section members, and as has already been mentioned a thousand of this number reside in the London area. The Committee would like to feel that the Section is being run according to *your* wishes and would therefore welcome the opportunity to adjust the activities in ways which you consider would prove beneficial to the Section.

Russian Revelations

On Wednesday 10th May members will have the opportunity of learning something of the Russian attitude towards civil aviation, when Mr. G. A. Yarotski, General Manager of Aeroflot, will lecture on his airline. It is hoped that some films of Russian aircraft will also be shown.

Paris Aero Show

Final arrangements have now been made for the week-end visit to the Paris Aero Show at Le Bourget. This will involve leaving London at 3.30 p.m. on Friday 2nd June and arriving back in London at 10.45 p.m. on the evening of Sunday 4th June. Initial response has been good and as the party must be limited to 35 those intending to take advantage of this visit should contact the Hon. International Visits Secretary, P. Hampton, Staff Mess, Royal Aircraft Establishment, Farnborough, Hants, at once. Total cost of the visit, including flight and surface fares and hotel accommodation, has been kept to the low figure of 10 guineas. A deposit of £3 should be sent with applications to Mr. Hampton, and the balance of the total cost *by 30th April at the latest.*

Opportunities at Farnborough

As a result of the publicity which has been given regarding the opportunity for members to visit particular departments at Farnborough, sufficient response has been received to organise a visit. This is planned for the beginning of May, to the Aerodynamics Department, and further applications should be made to the Hon. Visits Secretary as soon as possible.

Future Visits

The following visit has been arranged:—

Wednesday 10th May, Handley Page Ltd. (Afternoon).

Application for the visit should be made to the Hon. Visits Secretary; N. R. Craddock, 5 Oxleay Road, Harrow, Middlesex (Tel.: Pinner 3633), *at least three weeks before the date of the visit.*

Ninety-Sixth Annual Report of the Council 1960-1961

THE MOST outstanding event during the past session has undoubtedly been the completion and opening of the Lecture Theatre by Lord Brabazon on the 2nd December 1960. Since then we have held all Lectures in the new Hall and found the facilities very satisfactory. The additional office space is now in full use and the accommodation and arrangements for the staff are much improved thereby. Many people have been shown over the Theatre, and the projection equipment has been demonstrated to others seeking similar facilities.

The President and the Council are appreciative of the pleasure expressed by many Members of the Society on the appearance and functioning of the Theatre and are grateful for the support they have given in carrying this major project to a successful issue.

Despite the ups and downs of the Aircraft Industry the Membership of the Society continues to grow; it is now more than 11,000 and the field of interest and activity continues to widen.

The President and the Secretary, with other officers of the Society, have represented the Society on numerous occasions; at the Tercentenary of the Royal Society at the Albert Hall in July 1960; at the International Congress of the Aeronautical Sciences in Zurich, September 1960; and at the International Meeting of the Society of Automotive Engineers in Detroit in January 1961. Mr. E. T. Jones—Past President—and the Secretary attended the Annual General Meeting of the Institute of the Aerospace Sciences in New York, also in January 1961. The President has visited many of the Branches and has attended many functions of kindred engineering and scientific Societies.

Within the framework of the Society there are now three Sections—The Graduates' and Students' Section, the Astronautics and Guided Flight Section and the Rotorcraft Section—and three Groups, the Agricultural Aviation Group, the Historical Group and the Man Powered Aircraft Group. As will be seen from the individual reports, these Sections and Groups have each made good progress. Already there is talk about the possible formation of other Groups, *e.g.* a Ground Effect Machine Group, and where it arises, the Council are willing to consider the needs of an expressed demand.

The Annual Air Transport Course at Oxford continues to be held, attended by an ever-increasing number of Students. This year at the request of the Colonial Office, a Short Course was held in September 1960, to cater especially for Colonial Aviation administrators, and it seems likely that this will also be added to the Society's annual activities.

The President and the Council wish to thank all those who have helped to make the past year successful in the forwarding of new activities, and in consolidating those already established.

The Council 1960-1961

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Note—The Committees of Council, the Society's representatives on other Bodies and the Named and other Lectures are listed in Appendices 1, 2 and 3.

Annual General Meeting

The 95th Annual General Meeting of the Society was held at 4 Hamilton Place, London, W.1, on 5th May 1960, at which the Annual Report and Balance Sheets of the Royal Aeronautical Society and Aeronautical Trusts Limited for 1959 were approved. During the discussion on the Annual Report attention was drawn to an error in the first paragraph of the item on new By-Laws, page 234 of the April 1960 JOURNAL, where it was stated that the amendments to the new By-Laws were passed at General Meetings of members held on 3rd December 1958 and 4th May 1959. The meeting on 3rd December dealt solely with the question of the increased Annual Subscriptions and the paragraph in the Annual Report should have read as follows:—

> "The Privy Council have ratified the amendments in the Society's By-Laws which were passed at a General Meeting of Members held on the 4th May 1959."

The President reported the following elections to fill the vacancies on the Council:—

Sir Robert Cockburn (*Associate Fellow*)	Dr. G. S. Hislop (*Fellow*)
*Sir William S. Farren (*Hon. Fellow*)	*M. B. Morgan (*Fellow*)
*L. G. Frise (*Fellow*)	**N. E. Rowe (*Fellow*)**
	Air Marshal Sir Herbert D. Spreckley (*Fellow*)

*Re-elected.

A discussion ensued regarding the time of the Annual General Meeting and the question was put to the Vote. It was agreed that in future the Annual General Meeting should be held at 6.30 p.m.

The retiring President, Mr. Peter G. Masefield, presented the Society's Medals and Prizes for papers published by the Society in 1959 to the following recipients:—

The Simms Gold Medal	D. J. Farrar
The George Taylor (Australia) Gold Medal	R. Hafner
The Edward Busk Memorial Prize	E. C. Maskell and Dr. J. Weber
The Orville Wright Prize	R. Hicks
The Herbert Akroyd Stuart Memorial Prize	P. Lloyd
The J. E. Hodgson Prize	Professor A. R. Collar
The Branch Prize	Professor A. W. Morley
The Navigation Prize	E. G. C. Burt
The Usborne Memorial Prize	D. G. Drake
The Pilcher Memorial Prize	C. L. Bore

The retiring President, Mr. Peter G. Masefield, then inducted the incoming President, Dr. E. S. Moult. Mr. Masefield thanked the Members of the Council, the Members of the Society and the Staff for the support he had received during his term of office.

Dr. Moult paid a warm tribute to Mr. Masefield for all that he had achieved in the past year and presented him with a shield of the Society's crest and recording his term of office.

Dr. Moult then presented the *N. E. Rowe Medal* to Mr. C. J. Wood.

General Meeting of Voters of the Society

A General Meeting of Voters of the Society was held immediately after the Annual General Meeting and the following Resolution was passed unanimously:—

> "That the definition of the words 'The Society' in By-Law 1 of the By-Laws allowed the 11th of January 1960 be amended by adding the words 'and the Helicopter Association of Great Britain' after the words 'Institution of Aeronautical Engineers.'"

Air Transport Courses

A short Air Transport Course was held at Oriel College from 25th August to 3rd September 1960. This was arranged at the request of the Colonial Office, and was attended by 13 Students, all members of Colonial Civil Aviation Departments. Another such Course will be held in the Autumn of 1961.

The Sixth Air Transport Course is being held at Oriel College, Oxford, from 24th March to 15th April 1961. This will be attended by Students from Belgium, Iceland, India, Lebanon, Nigeria, Pakistan and Portuguese West Africa and from operators and firms in the United Kingdom.

The Secretary of the Society is Director of the Course, with Miss Croad as Secretary. Messrs. Barrowclough, Wheatcroft, Wilkinson and Tennant are again the Resident Lecturers. In addition there will be about 20 lecturers from the airlines and industry, and some eminent evening Speakers.

Graduates' and Students' Section 1960-61

During the year the Section Committee organised four lectures, a Brain's Trust, five visits, two dances, a film show and a cricket match. It also kept under review a number of matters affecting the interests of Graduates and Students.

Lectures and Visits

The average attendance at lectures fell below the record high level of the previous year. It is hoped that the combination of the appeal of the new theatre and a very varied and interesting programme organised for the coming year will return the average attendance to its previous high level. The Lectures are listed in Appendix 3.

Visits were arranged during the year to research establishments, aircraft companies, a brewery and to Associated-Rediffusion Television Studios. Most visits were well attended and in several cases were over-subscribed. As a result of the last visit to R.A.E. Farnborough, tours by small groups are being arranged to specialised departments at the Establishment. It is felt that these visits will appeal in particular to Students considering the possibilities of research work after graduation.

Social Activities

A new feature of the social programme was a cricket match between "The Committee" and "The Rest" which was held at the Cool Oak Lane ground on 24th June through the courtesy of the Handley Page Sports Club. The game was followed by an informal dance and the evening was considered very successful in spite of the inclement weather. The Annual Dance was held on 25th November 1960 and was the best attended for a number of years.

Other Activities

The Section's page in THE JOURNAL was used to keep members in touch with the Section's activities, as well as for publishing reports of lectures and visits. Among other matters covered were Companies' views on Recruitment, Post-Graduate Study in the U.S.A., a Student's views on Vacation Training and an account of a tour of the Industry to help in deciding where to work after graduating. As a result of a meeting in London between the Director of Student Activities of the American I.A.S. and the Section's Chairman an interchange of ideas and articles in each other's Journals was arranged.

The Committee is at present engaged in a survey of the geographical distribution of its members to help to decide whether it would be worth while to establish sub-sections in areas other than London, the ultimate aim being to make widespread the advantages at present restricted to London.

The Committee thanks all those who have given lectures or arranged visits on its behalf and also the members of the Society's Staff who have always been of every assistance.

Visits

1960

21st May: Vickers-Armstrongs (Aircraft) Ltd.
12th October: R.A.E. Farnborough.
5th November: Guinness Brewery.
6th December: Associated-Rediffusion Television Studios.

1961

18th March: N.P.L.
19th April: N.G.T.E. Pyestock.
10th May: Handley Page Ltd.
2nd-4th June: Paris Air Show.

The Astronautics and Guided Flight Section

The Third Annual General Meeting of the Section was held on Friday 8th July 1960 at 5.30 p.m.

The Chairman, Mr. A. V. Cleaver, announced the names of those elected to the Committee by ballot. These were:—Mr. W. H. Stephens (re-elected), Mr. J. E. Allen, Dr. W. F. Hilton. At the first meeting of the Committee, Mr. A. V. Cleaver was re-elected Chairman, and Dr. W. F. Hilton was elected Vice-Chairman.

The Lecture programme for the session—included in Appendix 3 of this report—has been well attended, and membership of the Section has increased from 535 to 577. A very successful All-day Symposium was held on 16th March on "The Training of Guided Missiles Engineers." The speakers included leading representatives of the three Services, the Universities, and Industry, and the afternoon was devoted to a lively and constructive discussion.

The Rotorcraft Section

An Extraordinary General Meeting was held on 13th January 1961 at 4.15 p.m. to present the final accounts and Liquidator's Report on the winding up of the Helicopter Association of Great Britain. Surplus assets were transferred to the Royal Aeronautical Society and as the Alan Marsh Fund was already well endowed were allocated to the Cierva Memorial Fund.

The First Annual General Meeting of the Rotorcraft Section was held on Friday 13th January 1961 at 4.30 p.m. The Chairman, Professor J. A. J. Bennett, announced the names of those elected to the Committee by ballot. Professor J. A. J. Bennett, Dr. G. S. Hislop and Mr. R. H. Whitby were re-elected, and Mr. O. L. L. Fitzwilliams and Dr. H. Roberts were elected to fill vacancies on the Committee.

At the first meeting of the Committee, Professor J. A. J. Bennett was re-elected Chairman, and Wing Cdr. R. A. C. Brie was elected Vice-Chairman.

During the year, nine lectures were held, all of which were well attended, and it was decided to hold a Cierva Memorial Lecture each year. The first Cierva Memorial Lecture was given by Professor J. A. J. Bennett on 16th February 1961. The Section's first Helicopter Rally and Garden Party was held on 11th June 1960 at Dunsborough Park, Ripley, by kind permission of Mr. and Mrs. Charles Hughesdon. This was attended by 13 helicopters and 550 members and guests. The first Annual Dinner of the Rotorcraft Section was held at the Dorchester Hotel on 8th September 1960, and 439 members and guests attended. Professor J. A. J. Bennett presided, and the chief speakers were Dr. E. S. Moult, President of the Society, and Mr. H. D. N. Wyatt, Chairman and Managing Director of British United Airways.

The Alan Marsh Medal was awarded to Flt. Sgt. B. Breach, R.A.F., and the Alan Marsh Award to Mr. A. C. Jolly. The Medal and the Award Certificate were presented to the winners at the Annual Dinner.

Historical Group

Subjects considered by the Steering Committee of the Group during the year have come under the following headings:—

(*a*) Records of historical interest.
(*b*) Centres of information.
(*c*) Museums and collections.
(*d*) Methods of study.
(*e*) Methods of propagation.

These headings have been taken as a guide for the first year's activities of the Group and will bear fruit within the course of the next two or three years. The series of lectures, inaugurated by Sir Thomas Sopwith is the first fruit of the discussion under "Methods of propagation."

The Steering Committee has also discussed or made suggestions on the following matters:—

(1) The New Aeronautical Gallery of the Science Museum. On this subject the Steering Committee has had the benefit of an address by Mr. G. W. B. Lacey who is in charge of the Aeronautical Collection.

(2) The provision of a permanent home for the Battle of Britain Hurricane and Spitfire aircraft retired from the Service.

(3) The formation of a National Aeronautical Museum.

(4) The making of film and sound recordings of pioneers of aeronautical history.

(5) The examination and possible preservation of some of the 80,000 pilots log books in the Public Record Office.

(6) The re-conditioning or reconstruction of historic aircraft including the overhaul and repair of the Society's Historical Collection.

In addition, the Steering Committee appointed Sub-Committees under the Chairmanship of Air Commodore A. H. Wheeler and Mr. J. L. Nayler, respectively, to advise the Secretary on the preparation of a Register of Historic Aircraft and a Register of Aeronautical History. Both of these registers are in the course of preparation. One practical result is the preparation of Historic Aircraft Plaques which are being presented to the owners of aircraft on the Register of Historic Aircraft. Eighty plaques have been completed and the first to be presented was given to Sir Thomas Sopwith on the occasion of his lecture on 21st November.

The first Annual General Meeting of the Group was held on 21st November 1960, at which a Committee was elected. Colonel R. L. Preston was re-elected Chairman for 1961. Membership of the Group amounts to 60.

Man Powered Aircraft Group

The past few months have been clouded over by the death of the Chairman, Mr. H. B. Irving, following a serious motor accident. He was a great supporter of the Group and his loss is a severe one for us all. Much of the development of the Group is due to his unfailing enthusiasm and energy in furthering the aims of the Group.

During the year, the Group has received projects from a number of designers and several of the designs appear to be worthy of further development. It is realised by the Committee that the research and development required on these machines will cost money and they therefore arranged for the individuals and or groups responsible for the designs to meet the Committee to discuss their problems. Following these meetings, the Committee has considered the financial help which could be given to these people out of the fund of nearly £5,000 received from individuals and firms. The Council would like to take this opportunity of thanking those members of the Committee and the various firms who have contributed to the fund, particularly Mr. Kremer, who contributed £2,500. At the date of this report, financial assistance up to £1,500 has been offered to a group at the University of Southampton and a similar amount to the Hatfield Man Powered Aircraft Club. This assistance is to enable the designs to be developed and built.

The Committee have obtained information on Wind Tunnels which could be made available for tests. Offers of help have also been received by model makers and others who would like to see the projects develop. The Committee feel this is a most encouraging state of affairs and they look forward to the development of these machines.

An interesting programme of five lectures was arranged for the session October 1960 to March 1961. The audiences, although small, have proved most enthusiastic and it appears certain that the Group will grow. The Annual General Meeting will be held on Friday 5th May 1961 at 5.0 p.m.

Agricultural Aviation Group

The Society's Agricultural Aviation Group was formed in April 1959, under the Chairmanship of Mr. S. W. G. Foster, A.F.R.Ae.S., and its aims are to further the use of aircraft in agriculture, forestry, pest control, fertilising, seeding, chemical application and similar subjects; and to provide facilities for those interested to meet and exchange ideas and information.

The Committee of the Group, which comprises most of the original Steering Committee together with three new members, took office at the Group's Annual General Meeting in May 1960; Mr. Foster was re-elected Chairman. The Committee, which holds office until the Group's Annual General Meeting on the 24th May 1961, is listed in Appendix 1.

Members of the Group and their friends visited Chesterford Park Research Station near Saffron Walden, Essex, last autumn and the Group is planning to visit the B.E.A. Engineering Base at London Airport in 1961. Six lectures were arranged for the 1960-61 Lecture session.

A suggested programme of lectures for the 1961-62 session has been presented to the Lectures Committee, including such subjects as marginal land, a contractor's review of the season's work, chemical ploughing and seeding from the air, a survey of the results of the experimental spraying of forest areas, and the use of Ground Effect Machines in agricultural work. It is hoped to arrange a joint discussion with the Royal Agricultural Society. A Working Party has been set up, under Mr. F. C. Clay and Mr. Foster, to collect and disseminate information on the design and installation of aerial equipment. The Bibliography on Agricultural Aviation, to be kept in the Society's Library, is progressing slowly and the Secretary of the Group will be glad to receive additional reference cards.

Divisions

As mentioned in the last Annual Report the President of each Division is now an *ex-officio* member of the Council and to keep them informed of the Society's business Council papers are sent to them each month.

The Council were very gratified to receive gifts from the Divisions for the Lecture Hall, particularly that from Australia of a Gavel made from Australian wood.

During the year a number of members of the Society have visited the Divisions and have taken the opportunity of meeting the overseas members and addressing them. Among those who have done so are Professor E. J. Richards, Mr. R. C. Morgan and Mr. E. C. Bowyer. Sir Roy Fedden, whose visit to the New Zealand Division last year was so successful, visited the Southern Africa Division in Johannesburg in March 1961 and was able to meet the President and other members of the Division for luncheon and a talk.

The Council hope that members will continue to inform the Secretary of their intention to visit these countries so that personal contact can be maintained with overseas members.

Branches

During the year Main Lectures have been held at Belfast, Chester, Luton, Southampton and Swindon, and the attendance at each lecture has been very good. The officials of the Branches made special efforts to ensure the success of these Meetings; the Council of the Society recognises this, and wishes to thank them for their efforts.

The 1960 Spring Branches Conference was held at Brough and was attended by about forty delegates. Each delegate was entertained by individual members of the Brough Branch, and this was much appreciated. It has now become established that the Spring Conference be held at a Branch, while the Autumn Conference is held in London.

The Autumn Conference was held on 11th December 1960 in the Lecture Theatre at 4 Hamilton Place. The President was able to attend, and during his talk to the delegates he pointed out that the new Theatre was their Theatre also. As a result of this the Weybridge Branch held a Branch lecture in the Lecture Theatre on 4th January 1961.

The Branches Page in THE JOURNAL has now been established for a year and in it is being recorded the History of each Branch.

The Branch Named Lectures in 1960-61 are listed on page 295.

Membership

The year 1960 provided a small but encouraging increase in the total membership of the Society. This increase, of 229, was brought about by a slight quickening in the rate of intake of new members coupled with a drop in the number of resignations and terminations. The total number of new members was 714 and the net gain, small though it is, coupled with the fairly high rate at which new applications are received may indicate the end of the temporary slackening in the upward curve of the Society's membership which has been evident for the past two or three years. Another interesting point is the continued pressure by members in the lower grades to transfer to senior classes of membership. The enthusiasm displayed by many members who are Students and Graduates for transferring to Associate Fellowship shows that this section of the Society's membership is very much alive.

The number of new Associate Fellows has risen sharply to 305 as compared with 168 in 1959 and the number of Associates has risen to 192 which is the same as that which was recorded in 1958. The total number of new Graduates has also risen, reaching 165, although there was a slight fall in the total number of new Students (173).

On the whole the trend of membership is encouraging and the figure of 11,000 in the total membership has now been passed. The uncertainty regarding the future which has hung over the aviation industry for the past two or three years has recently been reduced somewhat and this may have contributed to the rather more optimistic trend of the Society's membership. The table shows Membership as at 31st December 1960.

Second International Congress of the Aeronautical Sciences, Zurich, September 1960

The Second International Congress of the Aeronautical Sciences was held in Zurich, Switzerland, from 12th-16th September 1960.

The technical sessions were held in the Grosser Horsaal für Experimentalphysik of the Eidgenossische Technische

MEMBERSHIP AT 31st DECEMBER 1960

Grade	London Register	Australian Division	Southern Africa Division	New Zealand Division	Life and Honorary	Totals
Hon. Fellows	— (—)	— (—)	— (—)	— (—)	31 (H) (30)	31 (30)
Fellows	458 (450)	17 (18)	1 (1)	4 (4)	17 (H) (12)	514 (503)
					17 (L) (18)	
Associate Fellows	4705 (4528)	200 (193)	62 (67)	43 (43)	22 (H) (21)	5050 (4868)
					18 (L) (16)	
Associates	2143 (2139)	87 (87)	105 (107)	61 (60)	2 (H) (1)	2402 (2399)
					4 (L) (5)	
Graduates	1242 (1195)	41 (43)	3 (6)	6 (3)	— (—)	1292 (1247)
Students	1295 (1366)	36 (43)	12 (7)	5 (4)	— (—)	1348 (1420)
Founder Members	— (—)	— (—)	— (—)	— (—)	10 (H) (10)	10 (10)
Hon. Companions	— (—)	— (—)	— (—)	— (—)	8 (H) (8)	8 (8)
Companions	223 (160)	12 (8)	7 (7)	6 (4)	1 (H) (—)	255 (185)
					6 (L) (6)	
Temp. Hon. Members	— (—)	— (—)	— (—)	— (—)	53 (H) (53)	53 (53)
					144 (H) (135)	
TOTALS	10069 (9838)	393 (392)	190 (195)	125 (118)	45 (L) (45)	10963 (10723)

Figures in brackets are corresponding figures at 31st December 1959.

Hochschule. Dr. Theodore von Kármán, President of the I.C.A.S., presided. Papers were presented in English, French and German and interpreting equipment was provided.

A special Ladies' Programme was arranged. A Reception was held on Monday evening, 12th September, to which all delegates received invitations, and a Banquet was held on Friday evening, 16th September, in the Convention Hall.

The number of delegates from the United Kingdom attending the Congress was 43. This compares with 61 attending the first Congress held in Madrid in 1958.

Discussions are already taking place on arrangements for the Third Congress to be held in Stockholm in 1962.

Medals and Awards of the Society

Full particulars of the Medals and Awards of the Society were published in the June 1960 JOURNAL.

HONORARY FELLOWSHIP

The Council have pleasure in recording that Honorary Fellowship, the highest honour which the Society can confer, was awarded to the following in 1960:—

SIR GEORGE EDWARDS, C.B.E., B.Sc., F.R.Ae.S., Hon.F.I.A.S. (Managing Director of Vickers-Armstrongs (Aircraft) Ltd., and a Past-President of the Society).

PROFESSOR W. J. DUNCAN, C.B.E., D.Sc., F.R.S., F.R.Ae.S. (Professor of Aeronautics and Fluid Mechanics at the University of Glasgow and Chairman of the Aeronautical Research Council). (The Council regret to announce that Professor Duncan died in December 1960.)

Birthday Honours List, June 1960

The President and Council congratulate the following members who were included in the Birthday Honours List:—

G.C.B.
Admiral Sir Caspar John (*Companion*)
W. H. Stephens (*Fellow*)

K.B.E.
Dr. R. Cockburn (*Associate Fellow*)

K.B.
P. Ll. Hunting (*Companion*)

C.B.
Air Vice-Marshal R. A. Ramsay Rae (*Associate Fellow*)

O.B.E.
Commander E. N. Banfield (*Associate Fellow*)
R. J. Clayton (*Associate Fellow*)

M.B.E.
Flight Lieut. J. Beattie (*Associate*)
D. Cemm (*Associate Fellow*)

New Year Honours List, 1961

The President and Council congratulate the following members who were included in the New Year Honours List:—

C.B.
W. H. Stephens (*Fellow*)
Group Capt. A. W. Caswell (*Associate Fellow*)

C.B.E.
G. C. I. Gardiner (*Fellow*)
A. A. Rubbra (*Fellow*)

O.B.E.
A. W. Bedford (*Associate*)

Queen's Commendation for Valuable Service in the Air
T. W. Brooke-Smith (*Associate Fellow*)

Honours Awarded to Members

Sir Frederick Handley-Page, *Honorary Fellow*, and Past President of the Society, received the following honours: The Ludwig-Prandtl Ring at Bonn 1960, and the Albert Medal of the Royal Society of Arts.

Professor J. A. J. Bennett (*Fellow*) was awarded the Breguet Memorial Trophy for 1959 (awarded annually by the Royal Aero Club).

Sir Harry Ricardo (*Fellow*) received an Honorary Degree from Turin Polytechnic School.

The Enoch Thulin Bronze Medal of the Swedish Society of Aeronautics has been awarded to F. M. Owner (*Fellow*), R. R. Jamison (*Fellow*), Dr. S. G. Hooker (*Fellow*) and A. A. Lombard (*Fellow*).

T. W. Brooke-Smith (*Associate Fellow*) was awarded the Segrave Trophy by the Royal Automobile Club and the Britannia Trophy by the Royal Aero Club.

Lord Hives (*Honorary Fellow*) was awarded the Churchill Medal by the Society of Engineers.

Igor I. Sikorsky (*Honorary Fellow*) was awarded the Grover E. Bell Award by the American Helicopter Society.

Igor Alexis Sikorsky (*Associate Fellow*) was made an Honorary Fellow of the American Helicopter Society.

Sir Harold Roxbee Cox (*Fellow*) was made a Fellow of Imperial College of Science and Technology.

Squadron Leader W. R. Gellatly (*Associate Fellow*) was awarded the de Havilland Trophy by the Royal Aero Club.

A. W. Bedford (*Associate*) was awarded the Derry and Richards Memorial Medal by the Guild of Air Pilots and Air Navigators.

H. Sammons (*Fellow*) and E. E. Chatterton (*Fellow*) were awarded the George R. Henderson Medal of the Franklin Institute.

ROYAL AERONAUTICAL SOCIETY UNIVERSITY PRIZES

The following have been awarded Royal Aeronautical Society University Prizes for 1960:—

Cambridge University	D. W. Price, St. Catharine's College
Southampton University	A. J. Pretlove
Bristol University	J. Armitt
Imperial College	F. G. Ross and J. A. Holt (Joint Award)
Belfast University	D. L. I. Kirkpatrick
College of Aeronautics	C. G. B. Mitchell

There were no nominations for the prizes from Queen Mary College, London University or Glasgow University in 1960.

HENLOW CADET PRIZE

The Henlow Cadet Prize for 1960 was awarded to Pilot Officer A. Hedges.

ELLIOTT MEMORIAL PRIZE

The Elliott Memorial Prize presented to the Apprentices receiving the highest marks in the General Studies Examinations at Halton R.A.F. Station was awarded to Corporal Apprentice A. J. Phillips, Sergeant Apprentice A. W. Street and Sergeant Apprentice J. Swinden.

THE E. J. N. ARCHBOLD MEMORIAL PRIZE

The E. J. N. Archbold Memorial Prize was awarded to Mr. J. D. Bugden. This prize is awarded annually to the student gaining the highest marks in the City and Guilds Examination in the Aeronautical Engineering Division. Mr. J. D. Bugden is a student apprentice at the Bristol Aeroplane Company Technical College.

OTHER HONOURS AWARDED

Honorary Fellowship of the Institute of the Aerospace Sciences has been awarded to Mr. M. J. Lighthill.

Fellowship of the Institute of the Aerospace Sciences has been awarded to Mr. B. S. Shenstone and Mr. Handel Davies.

Associate Fellowship Examinations, 1960

The Associate Fellowship Examinations were held in June and December 1960, in the United Kingdom and overseas. The Council wish to record their thanks for the help given by the Examiners, the Staff of The Imperial College of Science and Technology and to those who organised the arrangements for the overseas candidates. Sixty-one candidates took Part I of the examination and 81 took Part II. The Examination was held at the following overseas centres:—

Bangalore, Bombay, Calcutta, Delhi, Hyderabad, Kanpur, Madras, Rajasthan, Poona, Karachi, Paris, Ghent, Sao Paulo, Sydney, Hong Kong, Toronto, Ontario, Singapore and Ghana.

THE ROYAL AE

(INCORPORATED BY

BALANCE SHEET

1959 Figures £		£ s. d.	£ s. d.	£ s. d.
	CURRENT LIABILITIES			
11667	Sundry Creditors		14850 12 0	
7813	Subscriptions and other amounts received in advance		7034 2 9	
				21884 14 9
	AERONAUTICAL TRUSTS LIMITED			
738	*Amount owing on Current Account*			— — —
	MAN-POWERED AIRCRAFT GROUP			
—	Henry Kremer Prize Fund		5000 0 0	
—	Donations and accrued Interest		3867 3 1	
				8867 3 1
	SURPLUS (subject to depreciation of Investments)			
	Reserve for Conferences and Courses			
	Balance at 31st December 1959		4056 6 0	
	Add transfer from Income and Expenditure Account		1500 0 0	
			5556 6 0	
	Less Expenditure less receipts during year		358 0 5	
4056			5198 5 7	
	Income and Expenditure Account			
	Balance at 31st December 1959	14324 5 2		
	Add Surplus of Income over Expenditure for year to date	1237 17 11		
			15562 3 1	
14324				20760 8 8
£38598				£51512 6 6

E. S. MOULT,
President.

G. P. BULMAN,
Honorary Treasurer.

REPORT OF THE AUDITORS TO THE MEMBERS

In our opinion the above balance sheet and the annexed income and Society Endowment Fund included in the annexed accounts of Aeronautical Trusts Ltd., and of its surplus for the year ended on that date.

We have obtained all the information and explanations which we considered in agreement with them and the said information and explanations.

3 Frederick's Place, Old Jewry, London, E.C.2.
21st March 1961.

AERONAUTICAL SOCIETY

BY ROYAL CHARTER 1949)

31st DECEMBER 1960

1959 Figures £		£ s. d.	£ s. d.
	CURRENT ASSETS		
1	Stock of Journals and other publications	1 0 0	
12996	Sundry debtors and payments in advance	17634 10 5	
14595	Balances at Bank and Cash in Hand	21992 16 5	
			39628 6 10
5600	**INVESTMENTS AT COST**		5600 0 0
	Market value 31st December 1960 £4,323 (1959 £4,590)		
	AERONAUTICAL TRUSTS LIMITED		
1	21 shares of 1/- each fully paid at cost	1 1 0	
—	Amounts due on Current Account	877 18 8	
			878 19 8
	PRINTED BOOKS, BINDINGS, OLD PRINTS, ETC.		
50	At nominal amount		50 0 0
	COLLECTION OF HISTORICAL AIRCRAFT (including Nash Collection)		
5355	At cost		5355 0 0
£38598			£51512 6 6

OF THE ROYAL AERONAUTICAL SOCIETY

expenditure account of the Society, together with the accounts of the Royal Aeronautical give a true and fair view of the state of the Society's affairs as at 31st December 1960.

necessary. In our opinion the Society has kept proper books, and the said accounts are

(*Signed*) PRICE, WATERHOUSE & CO.

THE ROYAL A

INCOME AND EXPENDITURE ACCOUNT FO

1959 Figures			£ s. d.	£ s. d.
	£			
		ESTABLISHMENT EXPENSES (less Amounts recoverable from Technical Committees)		
	2904	Ground Rent, Heating, Lighting, Insurance and Repairs		5501 12 7
		ADMINISTRATIVE AND OFFICE EXPENSES		
14759		Salaries, Wages and National Insurance	15181 10 6	
2609		Pension and Pension Premiums	2091 4 3	
2864		Printing and Stationery	2866 10 0	
3115		Postages and Telephones	2258 4 0	
261		Travelling	268 19 10	
193		Office Furniture and Equipment	343 10 6	
960		Other Charges	1532 2 10	
	24761			24542 1 11
		JOURNAL AND PUBLICATIONS		
4912		Salaries and Pension Premiums	5514 17 6	
20194		Printing	21957 16 9	
350		Printing Year Book	350 0 0	
3831		Postages and Wrappers	4141 2 10	
1688		Other Expenses	1746 11 6	
	30975			33710 8 7
		TECHNICAL COMMITTEES		
8606		Salaries and Pension Premiums	8152 6 4	
3485		Printing and other charges	5784 16 11	
	12091			13937 3 3
	794	EXAMINATIONS EXPENSES		805 13 4
	1197	MEETINGS AND LECTURES		1166 13 9
	2500	RESERVE FOR CONFERENCES AND COURSES		1500 0 0
	739	DINNERS AND RECEPTIONS		892 14 9
	206	SECTIONS AND GROUPS		399 10 8
		LIBRARY		
1704		Salaries and Pension Premiums	1749 15 9	
654		Expenses	722 5 8	
	2358			2472 1 5
	117	NASH COLLECTION MAINTENANCE EXPENSES		260 17 7
	780	BRANCHES SUBSIDIES		791 0 0
	230	PRIZES AND AWARDS		219 9 1
	300	CHARTER SCHOLARSHIPS		300 0 0
	579	LEGAL AND PROFESSIONAL CHARGES		685 16 6
	2112	Balance being Surplus of Income over Expenditure for Year carried to Balance Sheet		1237 17 11
	£82643			£88423 1 4

AERONAUTICAL SOCIETY

FOR THE YEAR ENDED 31st DECEMBER 1960

1959 Figures			£ s. d.	£ s. d.
£				
44091		MEMBERS' SUBSCRIPTIONS		47471 13 6
11211		DONATIONS AND GRANTS		13073 18 10
		INTEREST AND DIVIDENDS		
168		Interest on Investments (Gross)	168 0 0	
232		Interest on Deposit Account at Bank	653 2 11	
	400			821 2 11
		JOURNAL AND PUBLICATIONS		
9987		Advertising Revenue	10384 17 7	
11039		Sales	11380 8 7	
	21026			21765 6 2
		TECHNICAL COMMITTEES		
5382		Sales		4833 5 11
533		EXAMINATIONS FEES		457 14 0
£82643				£88423 1 4

AERONAUTICAL TRU

BALANCE SHEET

1959 Figures £		£ s. d.	£ s. d.	£ s. d.
	SHARE CAPITAL			
	AUTHORISED: 40 shares of 1s. each		2 0 0	
1	ISSUED: 21 shares of 1s. each fully paid			1 1 0
	ROYAL AERONAUTICAL SOCIETY ENDOWMENT FUND			
	CAPITAL ACCOUNT			
139021	Balance as at 31st December 1959		157779 8 10	
1966	*Add* Entrance Fees received during year		1923 8 0	
5	Donations received during year		— — —	
16787	Contributions to Lecture Theatre Appeal		16206 8 0	
157780			175909 4 10	
—	*Less* Loss on Realisation of Investments		23215 8 1	
157780			152693 16 9	
	INCOME ACCOUNT			
9104	Balance as at 31st December 1959	14637 17 10		
5534	*Add* Surplus of Income over Expenditure for year to date	2642 13 11	17280 11 9	
172418				169974 8 6
	ROYAL AERONAUTICAL SOCIETY EDUCATION FUND			
	INCOME ACCOUNT			
729	Balance as at 31st December 1959		1094 6 11	
365	*Add* Surplus of Income over Expenditure for year to date		476 3 2	
1094				1570 10 1
	EDWARD BUSK STUDENTSHIP IN AERONAUTICS			
	CAPITAL ACCOUNT			
5424	Balance as at 31st December 1959		5415 19 9	
8	*Less Loss on Realisation of Investments*		— — —	
5416				5415 19 9
	GEOFFREY DE HAVILLAND MEMORIAL FUND			
	CAPITAL ACCOUNT			
4237	Balance as at 31st December 1959		4258 17 5	
22	*Add* Donation received during year		23 0 0	
4259				4281 17 5
£183187	*Forward*			£181243 16 9

TRUSTS LIMITED

31st DECEMBER 1960

1959 Figures £		£ s. d.	£ s. d.	£ s. d.
1	CASH IN HAND			1 1 0
	ROYAL AERONAUTICAL SOCIETY ENDOWMENT FUND			
	Leasehold Property at cost *less* amounts written off			
	4, 8 and 9 Hamilton Place at cost	18941 9 4		
—	Additions at cost	90602 4 9		
		109543 14 1		
	Less Amortisation written off to date	14185 1 9		
7230			95358 12 4	
	Furniture at cost *less* depreciation			
	At cost	6396 1 11		
	Additions at cost	5846 6 0		
		12242 7 11		
	Less Depreciation written off to date	5338 5 5		
1311			6904 2 6	
146245	Investments at cost		69797 6 8	
	Market value 31st December 1960 £82, 993 (1959 £146,074)			
	Current Assets			
738	*Amount due from the Royal Aeronautical Society*		— — —	
1250	Sundry Debtors		15577 18 11	
15643	Balance at Bank		17414 2 9	
			205052 3 2	
—	*Less* Amount due to the Royal Aeronautical Society	877 18 8		
—	Sundry Creditors	34199 16 0		
			35077 14 8	
172418				169974 8 6
	ROYAL AERONAUTICAL SOCIETY EDUCATION FUND			
852	Investments at cost		852 5 11	
	Market value 31st December 1960 £842 (1959 £899)			
243	Balance at bank		718 4 2	
			1570 10 1	
(—1)	*Less amount due to Edward Busk Studentship Fund*		— — —	
1094				1570 10 1
	EDWARD BUSK STUDENTSHIP IN AERONAUTICS			
4182	Investments at valuation 31st December 1951		4181 10 0	
1226	Investments at cost		1226 6 6	
	Market value 31st December 1960 £4,460 (1959 £4,811)		5407 16 6	
7	Balance at bank		8 3 3	
1	*Amount due from the Royal Aeronautical Society Education Fund* ...		— — —	
5416				5415 19 9
	GEOFFREY DE HAVILLAND MEMORIAL FUND			
4226	Investments at cost		4226 2 2	
	Market value 31st December 1960 £2,936 (1959 £3,183)			
33	Balance at bank		55 15 3	
4259				4281 17 5
£183187	*Forward*			£181243 16 9

BALANCE SHEET—*Continued*

1959 Figures £		£ s. d.	£ s. d.	£ s. d.
183187	*Forward*			181243 16 9
	WILBUR WRIGHT MEMORIAL FUND			
	CAPITAL ACCOUNT			
2212	As at 31st December 1959		2211 17 11	
	INCOME ACCOUNT			
116	Balance as at 31st December 1959	117 13 2		
1	*Add* Surplus of Income over Expenditure for year to date	2 15 8		
			120 8 10	
2329				2332 6 9
	EDWARD BUSK MEMORIAL FUND			
	CAPITAL ACCOUNT			
1449	As at 31st December 1959		1449 6 1	
	INCOME ACCOUNT			
260	Balance at 31st December 1959	261 11 7		
2	*Add* Surplus of Income over Expenditure for year to date	14 4 8		
			275 16 3	
1711				1725 2 4
	PILCHER MEMORIAL FUND			
	CAPITAL ACCOUNT			
99	As at 31st December 1959		99 14 0	
	INCOME ACCOUNT			
86	Balance at 31st December 1959	86 10 4		
1	*Add* Surplus of Income over Expenditure for year to date	5 12 4		
			92 2 8	
186				191 16 8
	USBORNE MEMORIAL FUND			
	CAPITAL ACCOUNT			
109	As at 31st December 1959		109 2 5	
	INCOME ACCOUNT			
67	Balance at 31st December 1959	67 11 0		
1	*Add* Surplus of Income over Expenditure for year to date	5 9 4		
			73 0 4	
177				182 2 9
	HERBERT AKROYD STUART FUND			
	CAPITAL ACCOUNT			
691	As at 31st December 1959		691 9 0	
	INCOME ACCOUNT			
775	Balance at 31st December 1959	806 10 8		
32	*Add* Surplus of Income over Expenditure for year to date	31 12 4		
			838 3 0	
1498				1529 12 0
	R.38 MEMORIAL FUND			
	CAPITAL ACCOUNT			
982	As at 31st December 1959		981 13 10	
	INCOME ACCOUNT			
1356	Balance at 31st December 1959	1391 3 1		
35	*Add* Surplus of Income over Expenditure for year to date	84 17 4		
			1476 0 5	
2373				2457 14 3
£191461	*Forward*			£189662 11 6

TRUSTS LIMITED

31st DECEMBER 1960

1959 Figures £		£ s. d.	£ s. d.	£ s. d.
183187	*Forward*			181243 16 9
	WILBUR WRIGHT MEMORIAL FUND			
2286	Investments at cost ... ... Market value 31st December 1960 £1,988 (1959 £2,126)		2286 11 3	
43	Balance at Bank		45 15 6	
2329				2332 6 9
	EDWARD BUSK MEMORIAL FUND			
1706	Investments at cost ... ... Market value 31st December 1960 £1,423 (1959 £1,559)		1705 10 5	
5	Balance at Bank		19 11 11	
1711				1725 2 4
	PILCHER MEMORIAL FUND			
171	Investments at cost ... ... Market value 31st December 1960 £104 (1959 £115)		170 13 8	
15	Balance at Bank		21 3 0	
186				191 16 8
	USBORNE MEMORIAL FUND			
175	Investments at cost ... ... Market value 31st December 1960 £101 (1959 £112)		174 11 1	
2	Balance at Bank		7 11 8	
177				182 2 9
	HERBERT AKROYD STUART FUND			
1428	Investments at cost ... ... Market value 31st December 1960 £919 (1959 £1,012)		1428 5 10	
70	Balance at Bank		101 6 2	
1498				1529 12 0
	R.38 MEMORIAL FUND			
2303	Investments at cost ... ... Market value 31st December 1960 £1,477 (1959 £1,627)		2302 17 3	
70	Balance at Bank		154 17 0	
2373				2457 14 3
£191461	*Forward*			£189662 11 6

BALANCE SHEET—*Continued*

1959 Figures £		£ s. d.	£ s. d.	£ s. d.
191461	*Forward*			189662 11 6
	SIMMS GOLD MEDAL FUND			
	CAPITAL ACCOUNT			
528	As at 31st December 1959		527 15 9	
	INCOME ACCOUNT			
134	Balance at 31st December 1959	137 1 7		
3	*Add* Surplus of Income over Expenditure for year to date	2 18 0		
			139 19 7	
665				667 15 4
	ALSTON MEMORIAL FUND			
	CAPITAL ACCOUNT			
251	As at 31st December 1959		250 8 10	
	INCOME ACCOUNT			
71	Balance at 31st December 1959	81 2 7		
10	*Add* Surplus of Income over Expenditure for year to date	9 17 0		
			90 19 7	
332				341 8 5
	ALAN MARSH MEMORIAL TRUST FUND			
	CAPITAL ACCOUNT			
—	Balance at 1st March 1960 taken over from previous Trustees ...		2306 7 3	
	INCOME ACCOUNT			
—	Balance at 1st March 1960	149 7 5		
—	*Less* Excess of Expenditure over Income for period to 31st December 1960	57 15 0		
			91 12 5	
—				2397 19 8
£192458				£193069 14 11

REPORT OF THE AUDITORS TO THE

In our opinion the foregoing accounts give a true and fair view of the state of the surplus of the Funds for the year ended on that date.

We have obtained all the information and explanations which we considered necessary, agreement with them and with the said information and explanations, give in the prescribed

3 Frederick's Place, Old Jewry, London, E.C.2.

21st March 1961.

TRUSTS LIMITED

31st DECEMBER 1960

1959 Figures £		£ s. d.	£ s. d.	£ s. d.
191461	*Forward*			£189662 11 6
	SIMMS GOLD MEDAL FUND			
649	Investments at cost		648 10 1	
	Market value 31st December 1960 £457 (1959 £497)			
16	Balance at Bank		19 5 3	
665				667 15 4
	ALSTON MEMORIAL FUND			
317	Investments at cost		316 7 6	
	Market value 31st December 1960 £208 (1959 £229)			
15	Balance at Bank		25 0 11	
332				341 8 5
	ALAN MARSH MEMORIAL TRUST FUND			
—	Investments at cost		2000 0 0	
	Market value 31st December 1960 £2,000			
—	Sundry Debtors		26 10 0	
—	Balance at Bank		471 9 8	
			2497 19 8	
—	*Less* Sundry Creditors		100 0 0	
—				2397 19 8
£192458				£193069 14 11

MEMBERS OF AERONAUTICAL TRUSTS LTD.

Company's affairs and of the Funds administered by it as at 31st December 1960, and of the

In our opinion the Company has kept proper books, and the said accounts, which are in manner the information required by the Companies Act, 1948.

(*Signed*) PRICE, WATERHOUSE & CO.

AERONAUTICAL

INCOME AND EXPENDITURE ACCOUNTS

1959 Figures

£		£ s. d
	ROYAL AERONAUTICAL SOCIETY	
655	Amortisation of Leasehold Property	2474 0
222	Depreciation of Furniture	252 16
10	Legal Expenses	10 10
1357	Lecture Theatre Expenses	2702 9
5534	Surplus of Income over Expenditure for the year carried to Balance Sheet	2642 13 11
£7778		£8082 9
	ROYAL AERONAUTICAL SOCIETY	
325	Grants made in 1960	225 0
366	Surplus of Income over Expenditure for the year carried to Balance Sheet	476 3
£691		£701 3
	EDWARD BUSK STUDENTSHIP	
£231	Transfer to Royal Aeronautical Society Education Fund	£234 14
	GEOFFREY DE HAVILLAND	
£124	Transfer to Royal Aeronautical Society Education Fund	£123 18
	WILBUR WRIGHT	
100	1960 Lecture Premium	100 0 0
1	Surplus of Income over Expenditure for the year carried to Balance Sheet	2 15
£101		£102 15
	EDWARD BUSK	
21	1960 Award	21 0 0
18	Contribution to Wilbur Wright Memorial Fund	20 0 0
5	Contribution to Pilcher Memorial Fund	10 0 0
5	Contribution to Usborne Memorial Fund	10 0 0
1	Surplus of Income over Expenditure for the year carried to Balance Sheet	14 4
£50		£75 4
	PILCHER	
10	1960 Award	10 10 0
1	Surplus of Income over Expenditure for the year carried to Balance Sheet	5 12 4
£11		£16 2 4
	USBORNE	
10	1960 Award	10 10 0
1	Surplus of Income over Expenditure for the year carried to Balance Sheet	5 9 4
£11		£15 19 4
	HERBERT AKROYD	
21	1960 Award	21 0 0
32	Surplus of Income over Expenditure for the year carried to Balance Sheet	31 12 4
£53		£52 12 4
	R.38	
50	*1959 Award*	— — —
35	Surplus of Income over Expenditure for the year carried to Balance Sheet	84 17 4
£85		£84 17 4

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER 1960

1959 Figures £		£ s. d.
	ENDOWMENT FUND	
2849	Interest on Investments (Gross) ...	2892 1 4
1775	Interest on Investments (*less* Tax) ...	1860 12 5
103	Interest on Deposit Account at Bank (Gross) ...	240 2 0
1051	Refund of Income Tax ...	1044 13 10
2000	Rents receivable ...	2045 0 0
£7778		£8082 9 7
	EDUCATION FUND	
36	Interest on Investments (Gross) ...	42 10 0
300	Contribution from Royal Aeronautical Society (Charter Scholarship) ...	300 0 0
231	Transfer from Edward Busk Studentship in Aeronautics ...	234 14 6
124	Transfer from Geoffrey de Havilland Memorial Fund ...	123 18 8
£691		£701 3 2
	IN AERONAUTICS	
£231	Interest on Investments (Gross) ...	£234 14 6
	MEMORIAL FUND	
£124	Interest on Investments (Gross) ...	£123 18 8
	MEMORIAL FUND	
83	Interest on Investments (Gross) ...	82 15 8
18	Contribution from Edward Busk Memorial Fund ...	20 0 0
£101		£102 15 8
	MEMORIAL FUND	
50	Interest on Investments (Gross) ...	75 4 8
£50		£75 4 8
	MEMORIAL FUND	
6	Interest on Investments (Gross) ...	6 2 4
5	Contribution from Edward Busk Memorial Fund ...	10 0 0
£11		£16 2 4
	MEMORIAL FUND	
6	Interest on Investments (Gross) ...	5 19 4
5	Contribution from Edward Busk Memorial Fund ...	10 0 0
£11		£15 19 4
	STUART FUND	
53	Interest on Investments (Gross) ...	52 12 4
£53		£52 12 4
	MEMORIAL FUND	
85	Interest on Investments (Gross) ...	84 17 4
£85		£84 17 4

AERONAUTICAL

INCOME AND EXPENDITURE ACCOUNTS

1959 Figures £		£ s. d
	SIMMS GOLD	
20	1960 Award	20 0 0
3	Surplus of Income over Expenditure for the year carried to Balance Sheet	2 18 0
£23		£22 18 0
	ALSTON	
2	1960 Award	2 8 0
10	Surplus of Income over Expenditure for year carried to Balance Sheet	9 17 0
£12		£12 5 0

INCOME AND EXPENDITURE ACCOUNT

1959 Figures £		£ s. d
	ALAN MARSH	
—	1960 Award	10 0 0
—	Cost of Engraving Medal	2 5 0
—	Provision for Tuition Fees—Flight Training	100 0 0
		£112 5 0

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER 1960

1959 Figures £		£ s. d.
	MEDAL FUND	
23	Interest on Investments (Gross)	22 18 0
£23		£22 18 0
	MEMORIAL FUND	
12	Interest on Investments (Gross)	12 5 0
£12		£12 5 0

FOR PERIOD 1st MARCH to 31st DECEMBER 1960

1959 Figures £	MEMORIAL TRUST FUND	£ s. d.
—	Interest on Investments (Gross)	54 10 0
—	Excess of Expenditure over Income for the period carried to Balance Sheet	57 15 0
		£112 5 0

Donations

The Council acknowledge with grateful thanks donations which have been received during 1960 from the following:—

Bristol Aeroplane Company Limited.
de Havilland Holdings Limited.
Dowty Group Limited.
English Electric Group.
Hawker Siddeley Group.
Hunting Aircraft Limited.
The Ministry of Aviation.
Rolls-Royce Limited.
The Society of British Aircraft Constructors.
Vickers-Armstrongs (Aircraft) Limited.
Westland Aircraft Limited.

The Society has also received grants for Technical Work from:—

The Society of British Aircraft Constructors.
The Ministry of Aviation.

Technical Department

The Technical Department moved into the new offices on the fifth floor in September 1960. The fifth floor was carefully planned to suit the needs of housing as many staff as possible under the best conditions. A small committee room is incorporated and is generally used for meetings of the Society's Technical Committees, releasing committee room space elsewhere in the building.

A reasonably high level of issue of new data sheets has been maintained, as is indicated by the accounts, and it is obvious that the trends noted in the past few years have continued. The high demand for the type of service provided shows no signs of abating; rather does this demand continue to increase. This has been shown in 1960 by the requests and discussions leading up to new work which has been initiated. At the request of the Society of British Aircraft Constructors and the Ministry of Aviation a completely new committee and staff have been appointed to deal with transonic aerodynamic data.

The Transonic Aerodynamics Committee first met in September 1960 and the first new member of staff arrived in January 1961. Extensive enquiries made before the start of the work revealed a need for the collection of aerodynamic data relating to both supersonic and subsonic configurations at high subsonic speeds from as wide a field as possible.

It has also been possible to start work on another item, namely, internal aerodynamics. Not only is this work of considerable interest in aviation, where there is a strong tendency to move in a variety of directions and by a variety of means which have not been employed previously, but also in a wide range of technologies where aerodynamic techniques are of assistance. Accordingly, the Society is receiving the co-operation in this work of a number of non-aeronautical bodies having pertinent data to contribute.

Work proceeds in structures, aerodynamics, performance, fatigue and materials as the following account indicates.

Included in the eight multi-page data sheets issued in aerodynamics were thermodynamic properties, conditions behind normal shock waves and conditions behind oblique shock waves for air in dissociation equilibrium. Lift coefficient increment due to split flaps on thin wings was included as were the consideration of optimum area distributions of the transonic and supersonic area rules. Lift curve slopes and spanwise centres of pressure for isolated lifting surfaces at supersonic speeds completed this issue of new and revised data. Principal among the items under consideration for further data sheets are an extension of the data already issued on the real gas effects and the new work on internal aerodynamics.

Structures Data Sheets were considerably extended by an issue of eighteen data sheets, many of them in the multi-page format and covering the following subjects: Local buckling and crippling of struts, displacements of flexible circular frames under concentrated loads, buckling of unstiffened circular cylinders and the extension of the data on stress concentration factors. The work on unstiffened cylinders has proved to be of considerable interest to those engaged in the design and construction of missiles and rockets.

The new issue of data sheets on Performance is now being circulated. The subjects covered include an introduction to the correction of flight instruments, corrections to indicated air speed for static pressure error and to obtain equivalent air speed, an introduction to landing performance, a first approximation to the total landing distance from a 50 ft. height, the estimation of approach speed, of airborne distance and of ground run during landing. Performance work is currently continuing on a number of revisions and on compressibility correction to measured temperature, correction for lag error in pressure instruments, tyre runway coefficients of friction and flight dynamics.

Work on fatigue was somewhat delayed during 1960 by a lack of staff during an extended period. It is hoped to issue sheets later in 1961 which include further data on the effect of stress concentrations, the correlation of data on the endurance of dry riveted lap joints in aluminium alloys, correlation of data on the endurance of steel bolts in tension, on the static strength of cracked sheets and the effects of bolt pre-tensioning.

Volume II—Steels, of the AGARD Material Properties Handbook, was published in 1960 and includes 165 pages relating to the properties of those steels of greatest aircraft structural interest produced in the NATO nations. AGARD decided in 1960 to continue this series and work was put in hand on the third volume relating to magnesium, nickel and titanium. The same form of presentation will be used in this volume which will become available later in 1961. In addition, work is currently proceeding on additional and revised data on steels.

The work of the Technical Department is completely dependent upon the advice and assistance of its Committees, to which a new one, Transonic Aerodynamics, was added during the year. Service on these Committees involves a deal of concentration and hard work; the Society is well aware of its debt to these members. In order to ease the burden of Chairmanship to some extent, changes have been agreed and Vice-Chairmen have been appointed. The Committees are as follows (the year of original foundation is given in brackets):

Aerodynamics Committee (1942)

H. H. B. M. Thomas (*Chairman*)	R. L. Dommett	H. Metcalfe
	L. J. Fennell	J. D. Poole
Dr. D. W. Holder (*Vice-Chairman*)	J. W. Fozard	A. C. Southgate
	G. M. Lilley	Professor A. D. Young
J. R. Collingbourne	R. Melling	

Fatigue Committee (1955)

R. J. Atkinson (*Chairman*)	K. E. Cheverton	H. B. Howard
	H. L. Cox	N. H. Mason
R. H. Sandifer (*Vice-Chairman*)	A. J. Fenner	J. K. Williams
	Dr. G. Forrest	

Performance Committee (1946)

R. H. Whitby (*Chairman*)	D. G. Brown	R. T. Shields
	I. R. Collingbourne	J. C. Stevenson
C. F. Toms (*Vice-Chairman*)	G. E. Rogerson	M. C. Wilson
	P. Robinson	

Structures Committee (1940)

E. D. Keen (*Chairman*)	H. L. Cox	E. Loveless
	Professor W. S. Hemp	Dr. E. H. Mansfield
F. Tyson (*Vice-Chairman*)	H. B. Howard	
	D. James	

Transonic Aerodynamics Committee (1960)

A. B. Haines (*Chairman*)	E. Emslie	B. J. Prior
	Dr. D. W. Holder	R. Szukiewicz
H. H. Pearcey (*Vice-Chairman*)	T. Kerr	H. H. B. M. Thomas
	W. B. Lewis	
J. R. Collingbourne	R. Melling	

Members of the Technical Department have continued to assist in the organisation of many of the Society's activities. In particular they assisted at the Society's All-Day discussions and have represented the Society on various other bodies. Technical assistance has been given to individual members on a wide range of problems.

The Library

During the year under review, the Library service was maintained under difficult conditions. Due to the Theatre building programme almost all the periodical store was reduced to a huge unsorted pile of paper which had, at short and unpredictable intervals, to be moved from place to place. In addition to this, the Library itself was out of commission while it was taken over by the Technical Department and visitors had to have any material they required fetched by the Library staff.

Despite this and other troubles, loans made were still well into four figures, at 1,436. Acquisitions were well up to average at 319, and publishers showed appreciation of the reviews in THE JOURNAL by sending in the highest number of books so far, 205. The reports received showed the highest figure since records have been kept at 881.

Publications

In October the Publications Department, which had been accommodated at 8 and 9 Hamilton Place during the building of the Lecture Theatre, returned to 4 Hamilton Place.

As with most publications there is increasing difficulty for THE JOURNAL with more material to be published, more copies to be printed—12,000 copies a month now—increased competition from the new specialist Journals and steadily rising costs. The grouping of the major firms in the Aircraft Industry has affected the revenue and the Advertisement Managers have done well to maintain the advertisement revenue.

During the past year the same number of lectures was published in THE JOURNAL as in 1959, including those given before the Sections and Groups, and more submitted papers and technical notes were published; also, 19 more pages were devoted to the Library for reviews, additions and reports, while the overall number of pages in the 1960 volume was only 20 more than in 1959. Special preprints of the Astronautics and Guided Flight Section and Rotorcraft Section lectures and of those Group lectures published are available at 5s. a copy.

The Summaries of lectures published at the end of the Notices Section each month have proved of value to members; although every effort is made to publish them well in advance, this is not always possible, just as it is seldom possible to state with the summary, whether or not a lecture is to be published.

An innovation in 1960 was the Branches Page. This is compiled by Mr. G. Wansbrough-White, former Honorary Secretary of the Bristol Branch, and so far has mainly contained Branch histories, but it is hoped that the Branches will make increasing use of their page by contributing items of general interest.

In the Annual Report for 1959-60 reference was made to the proposed subject-author index for all the Society's publications since 1866. Mr. J. L. Nayler has now started work on the Index for 1950-1960.

A list of Members is planned for publication in 1961.

THE AERONAUTICAL QUARTERLY has increased its circulation by 40 per cent in the past five years to a value which is comparable with other research journals. Its price has remained the same since 1954, although the size of each issue is now 25 per cent greater and printing costs have risen substantially. The Editorial Board have made special efforts to attract research papers of high quality, either of direct aeronautical application or having a bearing on aeronautical problems, and the reduction of the time lag between receipt and publication of a paper to something less than six months is part of this policy. The Editor of THE AERONAUTICAL QUARTERLY is always pleased to hear, at an early stage, of research work which might later be suitably written up for the Quarterly and, if necessary, to discuss its presentation with the author.

The Council again wishes to thank the many members of the Society and non-members (in Industry, the Research Establishments and the Universities) who give such valuable assistance in refereeing papers for THE JOURNAL and THE AERONAUTICAL QUARTERLY.

As always, the co-operation given and the service received from the Society's printers has been of the highest order.

Obituaries, 1960

The Council regret to record the death of the following Members during the year:—

R. H. Adams (*Associate Fellow*)
Lady Mary Bailey (*Associate*)
A. C. Barlow (*Fellow*)
K. J. G. Bartlett (*Associate Fellow*)
J. D. Bendall (*Associate*)
E. F. Briggs (*Fellow*)
W. A. Caws (*Associate Fellow*)
Z. Ciolkosz (*Associate Fellow*)
H. Clayton (*Associate Fellow*)
C. Cooper (*Associate Fellow*)
G. Cornwall (*Fellow*)
W. Courtenay (*Associate*)
D. G. Croudson (*Associate Fellow*)
J. L. Davey (*Associate Fellow*)
A. J. Davis (*Associate Fellow*)
W. D. Douglas (*Fellow*)
W. J. Duncan (*Honorary Fellow*)
E. W. Fidler (*Associate Fellow*)
P. Field (*Associate Fellow*)
M. A. Forester-Bennett (*Graduate*)
P. R. C. Groves (*Associate Fellow*)
N. J. Hancock (*Associate Fellow*)
J. L. Jameson (*Associate Fellow*)
A. F. Lago (*Associate Fellow*)
A. F. McKeown (*Associate Fellow*)
G. B. McNab (*Associate*)
N. S. Norway (*Fellow*)
J. R. S. Overbury (*Associate*)
R. D. Peggs (*Fellow*)
H. L. Pitts (*Associate*)
E. P. Potter (*Associate Fellow*)
Sir David Pye (*Fellow*)
J. K. Reid (*Fellow*)
G. Tilghman Richards (*Fellow*)
E. Simpson (*Associate Fellow*)
S. W. Slaughter (*Associate Fellow*)
G. T. Smith-Clarke (*Fellow*)
C. F. C. Sneesby (*Associate Fellow*)
R. F. Stedman (*Associate*)
G. B. Stockman (*Associate*)
T. L. Sutton (*Associate Fellow*)
R. P. Tanner (*Associate*)
H. C. Tyler (*Associate*)
H. J. Watts (*Associate*)
H. E. Wimperis (*Fellow*)
T. F. Wookey (*Associate*)

The Staff

The President and Council are grateful for the work of the Secretary and the Staff, especially under the difficult circumstances of the past year.

Branch Named Lectures

The following is a list of the Named Lectures of the Branches given during the year:—

1960

BELFAST

20th October: FIRST SHORT BROTHERS COMMEMORATIVE LECTURE. The Short Brothers. J. Lankester Parker.

BROUGH

9th November: SEVENTH SIR GEORGE CAYLEY MEMORIAL LECTURE. Forty Years of Aviation Journalism. Major Oliver Stewart.

DERBY

7th November: FIFTH SIR HENRY ROYCE MEMORIAL LECTURE. Large Rocket Engines for Space Vehicles and Missiles. S. K. Hoffman.

SOUTHAMPTON

16th November: EIGHTH MITCHELL MEMORIAL LECTURE. Man Powered Aircraft. B. S. Shenstone.

1961

BRISTOL

1st March: EIGHTH BARNWELL MEMORIAL LECTURE. Some Aspects of Short-Haul Air Freighting. L. G. Frise.

HALTON-HENLOW

6th February: FOURTH TRENCHARD MEMORIAL LECTURE. The Nuclear Deterrent. Professor N. H. Gibbs—at Henlow.

HATFIELD

26th April: THIRD HALFORD MEMORIAL LECTURE. Dr. S. G. Hooker.

LONDON AIRPORT

10th March: THIRD SIR RICHARD FAIREY MEMORIAL LECTURE. Sailing. Uffa Fox.

MANCHESTER

15th March: SIXTH CHADWICK MEMORIAL LECTURE. Some Current Problems Facing the Aircraft Designer. J. C. Floyd.

WEYBRIDGE

15th February: NINTH R. K. PIERSON MEMORIAL LECTURE. Some Aspects of Science in Support of the R.A.F.—the work of the Scientific Adviser's Branch, Air Ministry. M. B. Morgan.

Appendix 1—Committees of Council 1960-1961

Future Policy Committee

DR. E. S. MOULT (*President*)
AIR MARSHAL SIR OWEN JONES (*President-Elect*)
MR. P. G. MASEFIELD (*Past President*)
SIR ARNOLD HALL (*Past President*)
SIR GEORGE EDWARDS (*Past President*)
AIR COMMODORE F. R. BANKS (*Vice-President*)
PROFESSOR A. R. COLLAR (*Vice-President*)
MR. B. S. SHENSTONE (*Vice-President*)
MAJOR G. P. BULMAN (*Hon. Treasurer*)

Finance Committee

MAJOR G. P. BULMAN (*Chairman and Hon. Treasurer*)
PROFESSOR J. A. J. BENNETT
SIR SYDNEY CAMM
MR. A. V. CLEAVER
SIR HARRY GARNER
DR. G. S. HISLOP
AIR MARSHAL SIR OWEN JONES (*President-Elect*)
MR. H. E. MARKING
MR. E. J. NICHOLL
MR. G. B. G. POTTER
DR. A. E. RUSSELL
MR. W. G. WILSON
MR. L. A. WINGFIELD (*Solicitor*)
MR. N. J. A. DEATON (*Secretary*)

Education Committee

MR. H. H. GARDNER (*Chairman*)
MR. E. G. BARBER
PROFESSOR J. A. J. BENNETT
MR. J. V. CONNOLLY
DR. D. M. A. LEGGETT
AIR COMMODORE J. R. MORGAN
PROFESSOR E. J. RICHARDS
GROUP CAPTAIN L. F. STANLEY
MR. E. G. STERLAND
MR. G. W. TREVELYAN
DR. L. G. WHITEHEAD
MR. T. A. WOLSTENHOLME
MISS B. CROAD (*Secretary*)

Lectures Committee

SIR GEORGE GARDNER (*Chairman*)
MR. E. J. CATCHPOLE
DR. W. CAWOOD
MR. HANDEL DAVIES
MR. S. D. DAVIES
MR. R. HAFNER
MR. D. KEITH-LUCAS
MR. W. N. NEAT
MR. L. F. NICHOLSON
DR. R. C. PANKHURST
MR. G. G. ROBERTS
PROFESSOR A. G. SMITH
MR. W. H. STEPHENS
MR. B. E. STEPHENSON
MR. W. TYE
PROFESSOR G. A. WHITFIELD
PROFESSOR A. D. YOUNG
MR. K. G. WILKINSON
MISS F. BARWOOD (*Secretary*)

NOTE: Dr. R. C. Pankhurst has agreed to serve until June 1961 during the absence abroad of Dr. W. P. Jones.

Medals and Awards Committee

SIR ARNOLD HALL (*Chairman*)
MR. C. ABELL
CAPTAIN W. BAILLIE
WING CDR. R. A. C. BRIE
SIR SYDNEY CAMM
SIR ROBERT COCKBURN
DR. J. W. DRINKWATER
MR. T. G. FARNSWORTH
SIR WILLIAM FARREN
DR. W. CAWOOD
MR. S. F. FOLLETT
DR. F. E. JONES
DR. W. F. HILTON
MR. H. B. HOWARD
MR. E. D. KEEN
PROFESSOR W. A. MAIR
MR. W. MAKINSON
PROFESSOR A. J. MURPHY
MR. A. A. RUBBRA
MR. J. C. C. TAYLOR
MR. W. TYE
MISS E. C. PIKE (*Secretary*)

Branches Committee

DR. A. M. BALLANTYNE (*Chairman*)
MR. W. R. BENDALL
MR. L. G. FRISE
MR. R. W. HILKEN
SQN. LDR. E. J. HOLDEN
MR. A. D. HOWARTH
AIR MARSHAL SIR OWEN JONES
MR. J. A. KIRK
MR. L. W. ROSENTHAL
MR. J. G. ROXBURGH
MR. G. WANSBROUGH-WHITE
MISS B. CROAD (*Secretary*)

Grading Committee

MR. M. B. MORGAN (*Chairman*)
MR. A. D. BAXTER
MR. L. BODDINGTON
MR. R. H. CHAPLIN
MR. E. C. CORNFORD
MR. F. B. GREATREX
AIR COMMODORE J. R. MORGAN
MR. R. C. MORGAN
MR. J. L. NAYLER
MR. J. G. M. PARDOE
MR. R. H. SANDIFER
AIR MARSHAL SIR HERBERT D. SPRECKLEY
DR. W. J. STRANG
MR. R. H. WHITBY
MR. A. S. C. LUMSDEN (*Secretary*)

Publications Committee

AIR COMMODORE F. R. BANKS (*Chairman*)
MR. E. L. BASS
MR. P. W. BROOKS
DR. A. BUCHANAN BARBOUR
MR. A. D. BAXTER
MR. G. PARR
DR. HENRY ROBERTS
MR. MARTIN SHARP
MR. H. F. VESSEY
MR. A. E. WOODWARD-NUTT
MRS. J. BRADBROOKE (*Secretary*)

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Appendix 2—Representatives on Other Bodies

Royal Society		
General Board of the National Physical Laboratory	Mr. M. B. Morgan	Sir Harry Garner
Executive Committee of the National Physical Laboratory	Sir William Farren	
National Committee for Theoretical and Applied Mechanics	Professor W. J. Duncan (*Chairman*) to Dec. 1960	Professor J. A. J. Bennett (*Chairman*) from Dec. 1960
British National Committee on Space Research	Sir Arnold Hall	
Institution of Electrical Engineers		
Committee on Regulations for the Electrical Equipment of Aircraft	Mr. C. G. A. Woodford	
Committee on Radio Equipment for Civil Aircraft	Mr. G. P. Parker	
Code Drafting Committee on the Proposed Code of Practice on the Measurement and Abatement of Radio Interference in Aircraft	Mr. G. P. Parker	
British Conference on Automation and Computation; Group B—Computation and Automatic Control Group	Professor E. J. Richards	
Joint Committee of the Royal Aeronautical Society and the Institution of Electrical Engineers on The Applications of Electricity in Aircraft	Mr. A. J. Barrett Mr. A. J. Cope Mr. J. F. Lewis Mr. E. Lloyd	Mr. W. H. McKinlay Mr. R. H. Woodall Mr. H. Zeffert
Institution of Mechanical Engineers		
British Conference on Automation and Computation: Engineering Applications Group (A)	Professor E. J. Richards	Dr. A. M. Ballantyne
British National Committee for Non-Destructive Testing	Mr. I. Grant-Murray	
Institute of Physics		
Committee on International Conferences on Stress Analysis	Mr. F. Tyson	Mr. H. L. Cox (*Deputy*)
College of Technology, Loughborough		
Governing Body	Mr. A. G. Elliott	
Advisory Committee in Aeronautical Engineering	Mr. E. D. Keen	
Royal Aircraft Establishment		
Technical College Advisory Board	Sir William Farren (*Chairman*)	Sir Harry Garner
College of Aeronautics, Cranfield		
Board of Governors	Sir Roy Fedden	Sir Harold Roxbee Cox
National Council for Technological Awards	Professor A. R. Collar	
Segrave Trophy Committee	Mr. J. R. Cownie	
City and Guilds of London Institute		
Advisory Committee on Aeronautical Engineering Practice	Dr. A. M. Ballantyne Sir Roy Fedden	Mr. B. S. Shenstone Sir Harry Garner
Association of Special Libraries and Information Bureaux	Captain J. L. Pritchard	
National Central Library	Captain J. L. Pritchard	
Regional Advisory Council for Technological Education		
Mechanical Engineering and Production Engineering Committee	Dr. A. M. Ballantyne	
University of London Senate		
Board of Studies in Aeronautical Engineering	Dr. A. M. Ballantyne	
Royal Technical College, Salford		
Engineering Advisory Committee	Mr. J. R. Ewans Dr. A. E. Russell	
Court of the University of Bristol		
Bristol College of Technology		
Board of Governors	Dr. A. E. Russell	
Engineering Advisory Committee	Mr. E. G. Sterland	
University of Cambridge		
Local Examinations Syndicate Joint Committee	Dr. A. M. Ballantyne	
Professional Classes Aid Council	Dr. A. M. Ballantyne	
Royal Air Force Education Advisory Committee	Mr. A. D. Baxter	
British Standards Institution		
Aeronautical Glossary Committee	Miss E. C. Pike	
Aircraft Industry Standards Committee	Mr. F. A. Kerry	
Technical Committee MEE/143. Gas Turbines	Mr. R. M. Cracknell	
Units and Symbols Standards Committee USM/-	Dr. A. M. Ballantyne	
Abbreviations and Symbols Committee USM/2	Miss E. C. Pike	
Lanchester College of Technology, Coventry		
Governing Body	Mr. A. A. Rubbra	
Mechanical and Production Engineering Advisory Committee	Mr. A. F. Varney	
Aeronautical Engineering Advisory Committee	Dr. W. F. Hilton	Mr. S. Allen
NATO Advisory Group for Aeronautical Research and Development		
Structures and Materials Panel	Mr. A. J. Barrett	
Federation Aeronautique Internationale	Mr. I. A. F. Donnelly (Rotorcraft Section Committee)	
Joint Committees for the Award of Higher National Certificates and Diplomas in Aeronautical Engineering in England, Wales and Northern Ireland	Professor A. R. Collar Air Commodore J. R. Morgan	Mr. H. H. Gardner Dr. A. M. Ballantyne

Appendix 3—Lectures 1960-61

THE FORTY-EIGHTH WILBUR WRIGHT MEMORIAL LECTURE by Mr. M. J. Lighthill on "Mathematics and Aeronautics" on 19th May 1960. Published in the July 1960 JOURNAL.

THE SIXTEENTH BRITISH COMMONWEALTH LECTURE by Mr. J. R. D. Tata on "The Story of Indian Air Transport" on 18th November 1960. Published in the January 1961 JOURNAL.

THE FOURTEENTH LOUIS BLERIOT LECTURE by Monsieur H. Ziegler, in London, on "The Development of Short Range Air Transport Through the Use of V/STOL Aircraft" on 23rd March 1961. A full report will be published in the JOURNAL.

THE FOURTH LANCHESTER MEMORIAL LECTURE by Professor A. D. Young on "British Universities and Aeronautical Research" on 22nd December 1960. Published in the March 1961 JOURNAL.

THE FIRST CIERVA MEMORIAL LECTURE by Professor J. A. J. Bennett on "The Era of the Autogiro" on 16th February 1961. A full report will be published in the JOURNAL.

20th October: MAIN LECTURE AT THE BELFAST BRANCH—Short Brothers Commemorative Lecture. J. Lankester Parker.

11th November: JOINT LECTURE WITH THE INSTITUTION OF ELECTRICAL ENGINEERS—The Future of Electrics and Electronics in Aircraft and Guided Missiles. The Rt. Hon. The Viscount Caldecote.

21st November: HISTORICAL GROUP—My First Ten Years in Aviation. Sir Thomas Sopwith.

22nd November: Basic Considerations of V/STOL Aircraft. P. L. Sutcliffe.

23rd November: GRADUATES' AND STUDENTS' SECTION—The British Space Programme. M. O. Robins.

28th November: AGRICULTURAL AVIATION GROUP—The Farmer's Viewpoint. J. B. Farrant.

29th November: ROTORCRAFT SECTION—The Design of Ground Effect Machines. R. Stanton Jones.

30th November: MAN POWERED AIRCRAFT GROUP—Some Aspects of Bird Flight. John Barlee.

1st December: MAIN LECTURE AT THE LUTON BRANCH—Ballistic Research Rockets, with particular reference to Black Knight. D. J. Lyons.

6th December: ASTRONAUTICS AND GUIDED FLIGHT SECTION—Solid Propellant Rocket Motors. Dr. G. H. S. Young and Dr. W. R. Maxwell.

7th December—AGRICULTURAL AVIATION GROUP—Grass, Soils and Fertilisers. I. A. Nicholson.

8th December: All-Day Symposium on Supersonic Transport Aircraft.

9th December: MAN POWERED AIRCRAFT GROUP—Film Show and Discussion. David Rendel.

12th December: HISTORICAL GROUP—Some Problems of Aeronautical History. C. H. Gibbs-Smith.

14th December: GRADUATES' AND STUDENTS' SECTION—B.O.A.C. and the Future. C. Abell.

15th December: Economic Lessons from Short-Haul Airline Operations. S. F. Wheatcroft.

20th December: Aircraft Shapes and their Aerodynamics for Flight at Supersonic Speeds. Dr. D. Kuchemann.

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3rd January: ASTRONAUTICS AND GUIDED FLIGHT SECTION—Film Show.

5th January: YOUNG PEOPLES' LECTURE—Gyroscope and Pendulum—The Modern Travel Agents. R. J. Lees.

6th/7th January: Joint Meeting with the College of Aeronautics and the British Interplanetary Society—Rocket Propulsion Symposium, at Cranfield.

9th January: HISTORICAL GROUP—Rebuilding and Flying Historic Aeroplanes. Air Commodore A. H. Wheeler.

11th January: GRADUATES' AND STUDENTS' SECTION—Brains Trust and Discussion Evening.

12th January: The Law versus Science in Aeronautics. H. Caplan.

13th January: ROTORCRAFT SECTION—Certification of Civil Transport Rotorcraft with particular reference to Multi-Engines. H. E. Le Sueur.

19th January: MAIN LECTURE AT THE SOUTHAMPTON BRANCH—Trends in Aircraft Propulsion. H. Pearson.

20th January: MAN POWERED AIRCRAFT GROUP—Gliding and Man Powered Flight. Lorne Welch.

23rd January: AGRICULTURAL AVIATION GROUP—Locust Control from the Air. Dr. R. C. Rainey.

24th January: Some Problems of Impact and Erosion in Flight. Dr. R. N. C. Strain, A. A. Fyall and D. C. Jenkins.

1st February: AGRICULTURAL AVIATION GROUP—The Economics of Agricultural Chemicals and Fertilisers. J. C. Pinder.

2nd February: MAIN LECTURE AT THE SWINDON BRANCH—Nuclear Propulsion for Aircraft. A. D. Baxter.

7th February: ASTRONAUTICS AND GUIDED FLIGHT SECTION—An Appreciation of Missile Structures. A. F. Newell.

8th February: GRADUATES' AND STUDENTS' SECTION—Flight Testing of VTOL Aircraft. T. W. Brooke-Smith.

10th February: MAN POWERED AIRCRAFT GROUP—Insect Flight. Dr. J. W. S. Pringle.

21st February: Newer Metallic Materials of Construction. Dr. N. P. Inglis.

1st March: Joint Discussion with the Institution of Electrical Engineers on The Training of Electrical and Electronic Engineers for the Aircraft Industry.

1st March: GRADUATES' AND STUDENTS' SECTION—Annual General Meeting and Film Show.

3rd March: ROTORCRAFT SECTION—Helicopter Approach Aids. H. W. Mitchell and S. G. Lennox.

8th March: MAIN LECTURE AT THE CHESTER BRANCH—Some Low Speed Problems of High Speed Aircraft. A. Spence and D. Lean.

13th March: HISTORICAL GROUP—The Evolution of Transport Aircraft. P. W. Brooks.

16th March: ASTRONAUTICS AND GUIDED FLIGHT SECTION—All-Day Symposium on The Training of Guided Missile Engineers.

17th March: MAN POWERED AIRCRAFT GROUP—Power Transmission Systems. S. S. Wilson.

21st March: Some Aspects of Buffeting. R. Fail.

29th March: AGRICULTURAL AVIATION GROUP—Atomisation. R. P. Fraser.

The following Lectures will complete the Programme in 1961:—

10th April: HISTORICAL GROUP—Joint Meeting with the Aircraft Recognition Society.

11th April: Direct Electrical Power Generation by Thermal and Chemical Means. Professor M. W. Thring.

12th April: GRADUATES' AND STUDENTS' SECTION—Man Powered Flight—Progress to Date. B. S. Shenstone.

19th April: AGRICULTURAL AVIATION GROUP—A Review of Current Developments in Agricultural Aviation. Dr. W. E. Ripper.

20th April: All-Day Symposium on Air Traffic Control.

25th April: On the Origin, Structure and Growth of Vortex Separations. E. C. Maskell.

5th May: ROTORCRAFT SECTION—The Helicopter—the First of the VTOL Aircraft. R. Hafner.

8th May: HISTORICAL GROUP—Continuation of the Joint Discussion with the Aircraft Recognition Society (from 10th April).

9th May: Structural Weight Estimations for Novel Configurations. M. E. Burt.

10th May: GRADUATES' AND STUDENTS' SECTION—Aeroflot. G. A. Yarotski.

18th May: ASTRONAUTICS AND GUIDED FLIGHT SECTION—The Agena Satellite and the Discoverer Programme. R. Smelt.

2nd June: ROTORCRAFT SECTION—Development of Stabilising Equipment for Helicopters. P. D. MacMahon.

Note.—The 1961 Wilbur Wright Memorial Lecture will be held on 12th September during the Anglo-American Conference.

THE LIBRARY

Reviews

SOLID PROPELLANT ROCKET RESEARCH. Vol. I of Progress in Astronautics and Rocketry. *Martin Summerfield* (Editor). *Academic Press, New York - London. 1960. 692 pp. Illustrated.* $6.50.

This volume is the first of a new series of books sponsored by the American Rocket Society, and represents an attempt to keep pace with the rapidly growing supply of technical papers which now far exceeds the capacity available for publication both in the Journal of the American Rocket Society, and in Astronautics. This volume contains a total of twenty-seven papers covering various aspects of solid propellant research work, and most of these were originally presented at the Symposium on Solid Propellant Research held at Princeton University on 28th and 29th January 1960. Six papers, however, have been drawn from backlog awaiting publication in the A.R.S. Journal.

The papers presented are in six main sections covering:—

A. Mechanical Properties of Grains (*5 papers*). These include problems of grain design, strength analysis and methods of calculating strain distribution in grains under internal pressure and with various conditions of restraint.

B. Steady State Burning Mechanisms (*4 papers*). Physical models are developed in an attempt to clarify the burning process of composite type propellants.

C. Combustion of Metals (*5 papers*). This group of papers deals with the influence of small quantities of powdered metals on the stability and burning properties of propellants.

D. Theories of Unstable Combustion (*5 papers*).

E. Experiments on Unstable Burning (*5 papers*). This batch of ten papers covers both theoretical and experimental aspects of unstable burning and diverse treatments are presented for the basic mechanism of interaction between small amplitude acoustic type oscillations in the combustion spaces of a motor and the flame zone at the burning face of the propellant.

F. Solid Propellant Ignition (*3 papers*). These papers deal with the location and processes of ignition leading to the initial flame, and whether it occurs in the gas or solid phase.

All the papers are written by experts in the particular fields of solid propellant research and are of considerable merit. The type and standard of printing, however, vary considerably from paper to paper, each being produced in its original form, and this results in the book as a whole giving an impression of untidiness which is not improved by errors in page titling and the fact that some mathematical formulae are handwritten while others use different kinds of type.

The book has little general appeal, except possibly as a work of reference, but it should be of very considerable interest to workers engaged in the specialised field of solid propellant rocket motor research.

Future volumes, in the course of preparation, will deal with Liquid Rockets and Propellants, Space Power Systems and Electrostatic Propulsion.—C. BAYLY.

THE MECHANICS OF VIBRATION. *R. E. D. Bishop and D. C. Johnson. Cambridge University Press, London. 1960. 592 pp. Diagrams.* £6.

A number of unusual features in the treatment of vibration theory distinguish this book from others of similar subject. The most interesting of these is that the theory is developed for what would appear to be for the first time in a textbook, almost entirely with the aid of the "receptance" concept. ("Receptance is the present day term for "mechanical admittance". It will be recalled that the late Professor W. J. Duncan advocated admittance methods and gave an account of their applications to vibration problems in an A.R.C. Monograph, R. & M. 2000.) Matrix algebra is not used in this book; the authors explain this by stating that their objective is to give the student and the engineer a true understanding of the physical problem, and not to allow this to become obscured by the mathematical facility afforded by matrices. Although the book purports to be written for the honours student in engineering, it would seem to take the study of vibration theory to much beyond that stage. It is, however, by no means a ready reference for the practising engineer; the emphasis throughout is on the essential fundamental principles, and the examples discussed are mostly the classical idealised spring-mass systems commonly used to illustrate these. Non-linear vibrations, self-excited oscillations, and references to experimental methods are all omitted.

The first three chapters give the fundamentals of vibration theory and develop the basic properties of receptances. A chapter on generalised co-ordinates and Lagrange's equations is followed by one on their application to systems having finite degrees of freedom, with receptance theory extended to generalised forces and co-ordinates and to principal modes. The taut string is chosen to introduce systems with infinite freedom, and its treatment is followed by a chapter on the approximate methods for the analysis of real systems using the methods of Rayleigh, Dunkerly and Southwell. Chapters are devoted to the torsional and longitudinal vibrations of uniform shafts and bars and to the flexural vibrations of beams. The treatment of the latter is particularly comprehensive and includes extensive tabulated data for frequency and mode calculations. Viscous damping and hysteretic damping are afforded separate chapters. Free vibration of damped systems is not discussed until the penultimate chapter, all previous discussions of the free vibrations of undamped systems having treated the free vibration as the limiting case of forced vibration when the frequency approaches a natural frequency and the forcing amplitude is diminished indefinitely. A final chapter introduces non-harmonic and transient vibrations.

The book demonstrates the ability of the receptance concept to simplify vibration analysis of complex systems. The treatment is very thorough indeed and as a result the volume is rather massive and costly. The book can be highly recommended to all, student and engineer alike, whose interests include the analysis of vibration.—C. SCRUTON.

THE WORLD OF MATHEMATICS, Vols. I-IV. *James R. Newman. Allen and Unwin, London. 1960. 2535 pp. Illustrated. 7 guineas.* (*4 Volumes.*)

For anyone whose basic training has been in mathematics this is a fascinating anthology; to others it must be a very readable collection of essays. Some are biographical, some historical and a great many indicate the uses of mathematics in a tremendous range of scientific and ordinary applications. They range from "Mathematics for Golfers" by Stephen Leacock to serious essays on the Great Mathematicians, and the diversity of the material in between can best be summarised by listing the headings of the various parts included in the four volumes:—

General Survey, Historical and Biographical, Arithmetic, Numbers and the Art of Counting, Mathematics of Space and Motion, Mathematics and the Physical World, Mathematics and Social Science, The Laws of Chance, Statistics and the Design of Experiments, The Supreme Art of Abstraction: Group Theory, Mathematics of Infinity, Mathematical Truth and the Structure of Mathematics, The Mathematical Way of Thinking, Mathematics and Logic, The Unreasonableness of Mathematics, How To Solve It, The Vocabulary of Mathematics, Mathematics as an Art, The Mathematician, Mathematical Machines: Can a Machine Think?, Mathematics in Warfare, A Mathematical Theory of Art, Mathematics of the Good, Mathematics in Literature, Mathematics and Music, Mathematics as a Culture Clue, Amusements, Puzzles, Fancies.

There are 133 selections and, to make sure that they

still have meaning when removed from their context, an introduction by the editor accompanies each one. This commentary is partly biographical and partly it indicates sources of parallel reading.

Many old favourites, such as Hardy's *A Mathematician's Apology*, Abbott's *Flatland* and Sir Ronald Fisher's *Mathematics of a Lady Tasting Tea* are represented and the editor will be recognised as co-author of *Mathematics and the Imagination*.

These volumes are, as they claim to be, "a small library of the literature of mathematics from A'h-mose the Scribe to Albert Einstein"—and a well-stocked library at that. Even the individual buyer will find seven guineas well spent in this direction.—E.C.P.

Additions to the Library

Adaptive Control Systems. E. Mishkin and L. Braun Jr. (*Editors*). McGraw-Hill, London. 1961. 533 pp. Diagrams. £6 8s. 0d. Results from a series of lectures (by eleven different authors) presented by the Electrical Engineering Department of the Polytechnic Institute of Brooklyn in September 1959 in the form of an extension course for a list of companies participating in the Industry Research Associates programme of the Polytechnic Institute of Brooklyn. The intention was to report rather broadly on the recent advances in the general area of feedback control systems, with emphasis on adaptive control systems. Linear systems, non-linear systems, adaptive control systems, and some topics in systems engineering are dealt with.

Air Cargo Terminal Planning Guide. Air Transport Association of America, 1960. 16 pp. Diagrams.

Axial Flow Fans. R. A. Wallis. Newnes, London. 1961. 366 pp. Diagrams. 50s. *To be reviewed.*

Boundary Layer Theory. Hermann Schlichting. (Translated by Dr. J. Kestin.) Fourth Edition. McGraw-Hill, London. 1960. 644 pp. Illustrated. £6 8s. 0d. Previous editions of this book have appeared in 1950 (in German, and reviewed in the November, 1951 JOURNAL, p. 747), in 1955 (in English, reviewed in the February, 1956 JOURNAL) and in 1958 (the second German edition). Now the English text of 1955 has been revised and brought into line with the 1958 German edition, which contained new material on compressible boundary layers, on thermal boundary layers and on transition. It is a valuable textbook and reference book.

Design of Concrete Pavements for Airports. Technical Committee, Wire Reinforcement Institute Inc., Washington. 1960. 96 pp. Illustrated. 3 dollars. A manual to serve as a handy reference for engineers responsible for the structural design of concrete pavements. It presents, with only limited discussion, the design criteria and practices that have been adopted by airport construction agencies after long years of research and experience. It is intended to provide the design engineer with essential data for preparing a detailed set of construction plans for reinforced concrete pavements. Drawings and tables have been included to reduce tedious calculations to a minimum.

Die Berechnung von rotierenden Scheiben und Schalen. Kurt Löffler. Springer-Verlag, Berlin. 1961. 241 pp. Diagrams. DM 42. *To be reviewed.*

Dover Reprints of Classics. A further series of these invaluable reprints of classics, at prices that the student and the lecturer can afford, has just appeared. Two of these latest seven deal with the dynamics of rigid bodies and the remainder with fundamental astronomy. The titles are: **Dynamics of a System of Rigid Bodies.** E. J. Routh. 1960. 458 pp. Diagrams. $2.35. (originally 1905). **Dynamics of Rigid Bodies.** W. D. MacMillan. 1960. 493 pp. Diagrams. $2.00. (originally 1936). **A Manual of Spherical and Practical Astronomy.** W. Chauvenet. 1960. Vols. I and II. 725 pp., 663 pp. Diagrams. $2.75, $2.75. (originally 1891). **An Introductory Treatise on Dynamical Astronomy.** H. C. Plummer. 1960. 345 pp. $2.35. (originally 1918). **A Compendium of Spherical Astronomy.** S. Newcomb. 1960. 455 pp. Diagrams. $2.25. (originally 1906). **Principles of Stellar Dynamics.** S. Chandrasekhar. 1960. 315 pp. Illustrated. $2.00. (originally 1942). **An Introductory Treatise on the Lunar Theory.** E. W. Brown. 1960. 304 pp. $2.00. (originally 1896).

Elasticity and Strength of Materials. Vols. I-III. I. Todhunter and K. Pearson. Dover Publications, New York. 1960. (Reprint of a classic). 936 pp., 762 pp., 546 pp. 12.50 dollars (3 vols.). *To be reviewed.*

Energy Theorems and Structural Analysis. J. H. Argyris and S. Kelsey. Butterworths, London. 1960. 85 pp. Diagrams. 21s. Sub-titled "A General Discourse with Applications on Energy Principles of Structural Analysis Including the Effects of Temperature and Non-Linear Stress-Strain Relations," and contained in stiff covers with spiral binding, this is a series of articles which appeared in *Aircraft Engineering* between October 1954 and May 1955.

Handbook of Aviation Meteorology. Air Ministry Meteorological Office. H.M. Stationery Office. 1960. 404 pp. Illustrated. 25s. *To be reviewed.*

Helicopter and other V/STOL Aircraft in Commercial Transport Service, The. Prepared by Economics Branch Office of Plans, F.A.A. 1960. 72 pp.

History of Australian Aviation. Stanley Brogden. Hawthorn Press, Melbourne. 1960. 192 pp. Illustrated. 35s. *To be reviewed.*

Influence of External Fuel Tanks on Wing Flutter of Slender Unswept Wings, The. ir. J. Yff. Delft. 1960. 82 pp. Illustrated.

Introduction to the Theory of Vibrating Systems, An. W. G. Bickley and A. Talbot. Oxford University Press, London. 1961. 238 pp. Diagrams. 30s. *To be reviewed.*

Jahrbuch der Wissenschaftlichen Gesellschaft fur Luftfahrt E. V. (WGL), 1959. H. Blenk (*Editor*). Friedr. Vieweg, Braunschweig. 1960. 438 pp. Illustrated. Contains 65 papers, eight of them in English, read at the W.G.L. Conference at Hamburg in 1959. When the remaining papers from the Conference are available they will be published in *Zeitschrift für Flugwissenschaften*. The proceedings cover a wide range—space flight, aerodynamics, parachutes and life-saving devices, rockets and materials—and emphasise the close link between aeronautical and marine engineering and the impossibility of demarcation between aeronautics and astronautics.

Lectures on Communication System Theory. E. J. Baghdady (*Editor*). McGraw-Hill, London. 1961. 617 pp. Diagrams. 97s. A collection of 23 lectures, mostly by staff at the Massachusetts Institute of Technology, derived from notes for a special summer programme on "Reliable Long-Range Radio Communication" offered at M.I.T. in August 1959 to practising communication engineers.

Liquid Rockets and Propellants. Vol. II of Progress in Astronautics and Rocketry series. L. E. Bollinger, M. Goldsmith and A. W. Lemmon, Jr. (*Editors*). Academic Press, New York. 1960. 682 pp. Illustrated. 6.50 dollars. A selection of technical papers based mainly on a Symposium of the American Rocket Society held in Ohio in July, 1960. Volume I in the same series, on solid propellants is reviewed in this JOURNAL (p. 299); this volume contains 28 papers on simulated high altitude testing, instrumentation for combustion instability, liquid propellant combustion, reaction kinetics, propellant selection and rocket engine design.

Manual on Aeroelasticity. W. P. Jones (*General Editor*). A.G.A.R.D., Paris. 1961. 49 pp. Diagrams. No price. *To be reviewed.*

Modern Airliner, The. Peter W. Brooks. Putnam, London. 1961. 176 pp. Illustrated. 30s. *To be reviewed.*

Moderne Leichtbautechnik Flugzeugbau und weiteren Anwendungsgebieten. Vol. I: Rumpf, Schalen- und Vollwandbauweise. Gerd Otto. Freidr. Vieweg, Braunschweig. 1960. 284 pp. Illustrated. DM 24.80. *To be reviewed.*

NASA—Industry Program Plans Conference. NASA, Washington. 1960. 123 pp. Illustrated. 6s. 9d. Contains 22 papers and the record of a Question-and-Answer Period. The basic purpose of the Conference (held in Washington in July 1960) was to provide for industrial management an overall picture of the NASA programme and to establish an adequate basis for subsequent conferences to be held at various NASA Centres. At these Centre Conferences, the scientific and technical content of NASA's programme plans will be further developed in sufficient detail to be of direct utility to scientists and engineers concerned with programme and project proposal formulation in organisations whose capabilities and interests are such as to overlap NASA's current and future requirements.

Outline of de Havilland History, An. C. Martin Sharp. Faber and Faber, London. 1960. 419 pp. 42s. *To be reviewed.*

Plasma Physics. J. E. Drummond. McGraw-Hill, London. 1961. 386 pp. Illustrated. 97s. Fourteen chapters contributed by nine American and two Russian authors. The outcome of a series of seminars in plasma physics held during 1957-58 at Stanford Research Institute, which was intended mainly to co-ordinate research in the San Francisco Bay region. Areas emphasised are basic plasma physics, magnetohydrodynamics and microwave plasma physics.

Proceedings of the Manned Space Stations Symposium. Institute of the Aeronautical Sciences, New York. 1960. 322 pp. Illustrated. 5 dollars. The 33 available papers, out of a total of 41, read at the Symposium in Los Angeles, U.S.A. in April 1960 and sponsored by the I.A.S. with the co-operation of N.A.S.A. and the Rand Corporation. The presentation is rough, but adequate, and the speed of publication justifies this; no discussions are included.

Report on the Elevated-Temperature Properties of Aluminum and Magnesium Alloys. American Society for Testing Materials, Philadelphia, U.S.A. 1960. 308 pp. 7 dollars. Data compiled by, and issued under the auspices of, the Data and Publications Panel of the A.S.T.M.-A.S.M.E. Joint Committee on the Effect of Temperatures on the Properties of Metals. Summarises elevated-temperature, tensile and creep-rupture properties of some 50 current commercially-established aluminium and magnesium alloys that would normally be used at elevated temperatures.

Satellites and Space Travel. J. W. R. Taylor and M. Allward. Ian Allen, London. 1960. 64 pp. Illustrated. 3s. One of the Ian Allen "a b c" series of booklets, this traces the history and purpose of artificial satellites and lists all the types so far launched, with such details as are available, including launching vehicles and space probes.

Selected Papers on Stress Analysis. Institute of Physics. Chapman and Hall, London. 1961. 114 pp. Illustrated. 50s. 51 papers in English, French or German were discussed at The Institute of Physics Stress Analysis Group Conference, held at Delft in 1959, the main topic being methods of stress analysis and their application. Some of these papers had already been published and in others the physical aspect was subsidiary to wider interests, so that they were unsuitable for reproduction in full here. In this volume 18 papers are printed in the forms in which they were presented, in their original languages, together with summaries in the three languages of the conference. There is an English résumé of the remaining 33 papers with a list of titles and authors with their addresses, so that more information on the topics covered can be obtained from the author.

Statistical Theory of Communication. Y. W. Lee. John Wiley, London. 1960. 507 pp. Illustrated. 134s. Developed from a graduate course at the Massachusetts Institute of Technology. Intended for the first-year graduate student it presents "a physically motivated and systematic account of the statistical theory of communication—an account that includes essentially all of the basic elements." It is confined to linear systems, but the last chapter is devoted to the synthesis of linear systems by orthonormal functions because of their importance in the statistical theory of optimum non-linear systems.

Systems Analysis View of Longitudinal Flying Qualities, A. D. T. McRuer, I. L. Ashkenas and C. L. Guerre. Wright Air Development Division Technical Report 60-43. January, 1960. 108 pp. Diagrams.

Testing Time. Constance Babington Smith. Cassell, London. 1961. 224 pp. Illustrated. 30s. *To be reviewed.*

Vorlesungen Uber Nicht-Euklidische Geometrie. Felix Klein. Chelsea Publishing Company, New York. 1960. 326 pp. Diagrams. No price. (*In German*). A reprint of a classic on non-Euclidean geometry, originally published in 1927.

Wave Propagation in a Turbulent Medium. V. I. Tatarski. (Translated by R. A. Silverman). McGraw-Hill, London. 1961. 285 pp. 76s. A Russian monograph describing the phenomena associated with the propagation of electromagnetic and acoustic waves through atmospheric turbulence. It approaches the subject from both a theoretical and an experimental point of view, placing special emphasis upon important Russian contributions to the field, some of them very recent, and most of them not previously obtainable in English. Emphasises the application to phase and amplitude fluctuations, scintillation of stars, radio scattering and so on. The covers are stiff (like the price) but the pages are only photo-reproduced typescript.

World Aviation Directory. Marion E. Grambow (*Editor*). American Aviation Publications. Washington. 1960. 1157 pp. 13 dollars. The Winter 1960-61 (No. 42) issue of this valuable reference work shows an increase of 75 pages over the previous. The well-established pattern remains the same and, coming from a firm responsible for a dozen aviation publications, the directory can be assumed to be authoritative. The agent in this country is Norall and Hart Ltd., 28 Bruton St., London, W.1.

S.A.E. PREPRINTS — 1961 International Congress — 9th-13th Jan. Detroit

266C Major problems of an overhead rapid transit. L. F. Chadenson and J. L. Bourgoin.

266D The Autoline—a missing link in city to city transportation. A. A. Atwell and R. F. McLean.

266E Progress in skycrane development. W. W. Lysak.

266F The development of steep gradient aircraft for short-haul transportation. L. L. Douglas.

266G Mass transportation by high-speed VTOL. H. V. Borst and J. M. Mergen.

270A Status of GEM developments. M. F. Southcote.

270B Marine air cushion vehicles. P. G. Fielding.

270C Ground-effect machine applications in mixed terrains. M. M. Cutler and A. F. Kossar.

270D A GEM for amphibious support. J. L. Wosser and A. J. Van Tuyl.

275A Some effects of runway slush and water on the operation of airplanes, with particular reference to jet transports. W. B. Horne and U. T. Joyner.

275B Clearing snow off runways at high speed. D. B. Rees.

275C Determining and reporting the braking qualities of icy or snow-covered runways. B. Holmer and G. Antvik.

279A Initiation and some controlling parameters of combustion in the automobile engine. J. S. Clarke.

280C Cooling for hypersonic aircraft structures. H. Mund.

283A Passenger handling for the jet age; the airport mobile lounge. J. M. Martin.

283B Proposed 463L materials handling support system. M. E. Peterson and C. M. Edmonds.

283C Payload—density—mechanization as applied to all-cargo aircraft. J. A. Morley.

283D Prospects for the use of mechanized cargo-handling systems in Europe. R. Maurer.

297A Army's view of the future. A. G. Trudeau.

297B Direct energy conversion. J. T. Hayward.

297C Forecasts for flight vehicle power. G. W. Sherman.

302A Mechanization of minimum-energy automatic lunar soft-landing systems. C. M. Mears and R. L. Peterson.

302C Human factors of the lunar logistics mission. R. O. Lowrey and J. T. Ray.

302D Lunar exploration systems. N. W. O'Rourke.

302E Long time exposure of hydraulic controls in space environments. A. B. Billet.

302F Ground based microwave system for spot landing of space vehicles. M. I. Beers *et al.*

312A Foundations of engineering magnetohydrodynamics. A. B. Cambel.

312B MHD applications for space and ground power. W. McIlroy and A. E. Kunen.

312C Some imaginative applications of magnetohydrodynamics to automotive engineering. M. C. Gourdine.

314A Post university on-the-job training for engineers. E. J. Manganiello and V. F. Hlavin.

Reports

AERODYNAMICS

BOUNDARY LAYER

The applicability of a sine series velocity profile in a two-dimensional incompressible laminar boundary layer. G. Kurylowich. U.T.I.A. T.N. 29. *July* 1960.
An account is given of the adaptibility of a sine velocity profile by developing a solution similar to the fourth degree expansion of Pohlhausen. The trigonometric results are presented in tabular form for use in the determination of flow quantities in two-dimensional boundary layers and a comparison is made with Pohlhausen and Thwaites. The results are used in the analysis of the flow over an infinite cylinder.—(1.1.1.1).

COMPRESSIBLE FLOW

Tables of flow functions for a simple non-steady expansion wave. A. Roshko and M. Rubenstein. Douglas Report E.S. 40031. 1960.
The nature of a non-steady expansion wave and its equations are reviewed. Tables and charts of twelve functions of a non-steady wave are presented for $\gamma=7/5$ and $5/3$ using the dimensionless flow speed as the independent parameter.—(1.2.3.2× 1.5.1.4).

Aerodynamics of blasts. I. I. Glass. U.T.I.A. Review 17. 1960.
Glass spheres and cylinders are pressurised by means of compressed gases or combustible mixtures and are shattered to generate an explosion. Similar methods can be used for implosions, underwater explosions, and wave interactions. The method has proved valuable in the study of many basic properties of spherical and cylindrical blast phenomena that have been investigated using piezo-pressure gauges and several schlieren and shadowgraph techniques. Consideration is given to intense explosions from concentrated energy sources for spherical, cylindrical and planar blasts, and explosions and implosions generated from finite sources with the same geometries. Blast-wave simulators for aerodynamic tests and the dynamic testing of structural components are discussed.—(1.2.3.2×1.12×21.3.3).

Reflection of a plane acoustic shock by a surface of revolution. P. Mandl. N.R.C. Report L.R. 289. *Aug.* 1960.
The influence of a structure on the pressure field and form of a passing shock wave and that of the shock wave on the structure are of considerable interest. Existing two-dimensional theory is extended to the case of bodies of revolution. The resulting series solutions permit certain conclusions about the transient loading on a structure as a function of the principal curvatures of its boundaries. When the solutions are applied to the particular case of a spherical reflector, they permit the transient loading and the blast impulse at various positions on the boundary to be calculated, for various forms of incident front. —(1.2.3.2).

Essais de soufflage au tunnell hydrodynamique a visaulisation. H. Werle. O.N.E.R.A. N.T. 61. 1960.
The effects of blowing on the flow around a large variety of models has been analysed using flow visualisation techniques in the hydrodynamic tunnel at O.N.E.R.A. Some results of these low speed experiments are presented. Contains:— fundamental research; blowing tangential to the surface; blowing normal to the surface; blowing at the base of the model; applications to aerodynamic problems; blowing over a flap; jet flaps; jet-operated ground effect machine; jet at the base of an aircraft or missile.—(1.2.3.2×1.5.1.4).

Étude expérimentale des ondes de choc produites par décharges d'un condensateur dans un tube a gaz. R. Der Agobian. Pubs Sc et Techs. 364. 1960. (*In French.*)
The detection and study of the propagation of shock waves produced by the discharge of a condenser in a tube of gas has been accomplished in two ways (an optical method and a method using high frequency radio waves) by producing in the route of the shock wave a self driven gaseous plasma. The shock wave which produces in its passage an increase of temperature and density can be used to advance the study of the phenomena of recombination and of collision in the plasma. —(1.2.3.2×32.2.2×34).

CONTROLS

Charts for low-speed characteristics of two-dimensional trailing-edge flaps. H. C. Garner. R. & M. 3174. 1960.
The charts have crystallised from long-term researches at the N.P.L. on the lift, pitching moment and hinge moment for aerofoils with plain trailing edge flaps. Given the ordinates of an aerofoil, the flap chord, the Reynolds number and fixed positions of boundary layer transition, the six independent derivatives of the aerofoil-flap combination in steady incompressible flow may be estimated. The likely accuracy of values obtained may be assessed. Some formulae are suggested to allow for differential transition.—(1.3.4×1.10.1.1).

Vortex-lattice treatment of rectangular wings with oscillating control surfaces. D. E. Lehrian. R. & M. 3182. 1960.
The vortex-lattice method for simple harmonic motion of general frequency is used to calculate the derivatives for rectangular wings with oscillating constant-chord flaps. The discontinuous chordwise boundary condition associated with full-span flaps, is replaced by a continuous equivalent downwash which is determined on the basis of two-dimensional oscillatory theory. In the particular case when the frequency tends to zero, the equivalent downwash is obtained on a distinct quasi-steady basis; stability derivatives are then evaluated by using an alternative form of the vortex-lattice method for low frequency. To allow for the spanwise discontinuity due to outboard flaps, a further adjustment is made to the boundary conditions by the use of partial-span downwash factors.—(1.3.4×1.10.1.2×2).

*Measurements of the control force-time relations for sudden movements of the controls. J. L. Overbeek. N.L.L.-T.N. V.*1816. *Dec.* 1958.
The time required by a pilot to achieve maximum control forces was determined experimentally. Tests have been performed by means of a test device, consisting of a Harvard fuselage, which was adapted to this purpose. Measurements were performed for the directional, lateral and longitudinal controls with 3 different control stiffnesses.—(1.3×1.8.0.2).

FLUID DYNAMICS *see also* AIRCRAFT OPERATION

A method for calculating the pressure distribution of a body of revolution moving in a circular path through a perfect incompressible fluid. F. Vandrey. R. & M. 3139. 1960.
The method is based on the use of source distributions on the surface of the body. Their strength is determined by solving three integral equations corresponding to the elementary cases of a longitudinal translation, a lateral translation and a rotation of the body about a lateral axis. The distributions of the relative velocity on the surface are then obtained by integrations. The complete solution for any case is obtained by a linear combination of the three elementary cases.—(1.4.1).

Measurements of two-point correlations of velocity near a circular cylinder shedding a Kármán vortex street. M. T. el Baroudi. U.T.I.A. T.N. 31. Jan. 1960.—(1.4×5.6).
Results of an experimental investigation of two-point correlations of velocity near a circular cylinder shedding a Kármán vortex street are presented. The measurements were made along a line parallel to the generator of the cylinder which is at 90° from the upstream direction. The cylinder was mounted transversely in an air stream, and two hot-wire probes were used as anemometers.—(1.4×5.6).

INTERNAL FLOW *see also* COMPRESSIBLE FLOW

Stall propagation in a cascade of airfoils. A. R. Kriebel et al. *N.A.S.A. T.R. R*-61. 1960.
An experimental investigation of stall propagation in a stationary circular cascade in which high-speed schlieren and interferometer photography is used is described. This investigation suggests an analytical approach to the study of stall propagation which is valid only for an isolated blade row in an infinite flow field but which is not restricted to small unsteady perturbations or to an assumed simplified cascade geometry. Conditions necessary for the existence of the assumed type of stall cells are described and equations are derived for the velocity of stall-cell propagation.—(1.5.4.1×2×1.5.2.1).

The effect of diameter ratio on the performance of a low-stagger axial-compressor stage. R. A. Jeffs and R. G. Adams. R. & M. 3151. 1960.
Low speed tests have been carried out on a family of three single stage compressors of different diameter ratios.—(1.5.2.1).

Pressure fluctuations near a cold, small-scale air jet (measurement of space correlations). R. E. Franklin and J. H. Foxwell. R. & M. 3162. 1960.
Gives details of experimental observations on a 2 in. model jet. The observations consist of velocity distributions, root-mean-square pressure fluctuations in the field round the jet and space correlations of the fluctuating pressures in limited regions near to the jet. It is considered that the main interest lies in the space correlations observed by using fine-bore probe microphones and correlation equipment.—(1.5.1×27.1×5.6).

Die Berechnung der Druckverteilung an dicken Gitterprofilen mit Hilfe von Fredholmschen Integralgleichungen zweiter Art. E. Martensen. Max-Planck-Inst. Mitt. 23. 1959.—(1.5.4.1).

LOADS *see* TESTING AND INSTRUMENTS
AEROELASTICITY

STABILITY AND CONTROL *see also* CONTROLS
WINGS AND AEROFOILS

Theoretical analysis of the longitudinal behavior of an automatically controlled supersonic interceptor during the attack phase. O. B. Gates and C. H. Woodling. N.A.S.A. T.R. R-19. 1959.
Control of the interceptor's flight path is obtained by use of a pitch rate command system. Topics considered included selection of system gains, effects of non-linear drag, lift, and pitching moment, effects of initial tracking errors, discussion of normal acceleration limiter, limitations of control-surface rate and deflection, and effects of neglecting forward velocity changes of interceptor during attack phase.—(1.8.2.1).

The design of feedback control systems containing a saturation type nonlinearity. S. F. Schmidt and E. V. Harper. N.A.S.A. T.N. D-324. Sept. 1960.
Equations for stable and unstable plants whose transfer functions are of second, third, or fourth order are derived. Optimum response times calculated for a wide range of damping and time constants are presented. Effects of a single zero in the plant transfer function are derived. Examples of optimum saturated control systems for tracking with the smallest error possible are derived.—(1.8.0.1×5.7×22).

Low-speed aerodynamic characteristics of a model of a hypersonic research airplane at angles of attack up to 90° for a range of Reynolds numbers. J. S. Bowman and W. D. Grantham. N.A.S.A. T.N. D-403. Sept. 1960.
Static force tests have been made on a model to determine the aerodynamic forces and moments up to an angle of attack of 90° and high sideslip angles for a range of Reynolds numbers, based on the mean aerodynamic chord, which correspond to dynamic pressures of 15 to 100 lb./ft.^{2} (Mach numbers from 0·10 to 0·27). The model was tested in the clean configuration with various horizontal tail settings, horizontal tail off, lower rudder off, fuselage alone, and with various size strakes and slats on the nose of the model.—(1.8.0.2).

WINGS AND AEROFOILS *see also* CONTROLS
AEROELASTICITY

Preliminary results of low speed wind tunnel tests on a Gothic wing of aspect ratio 1·0. *D. H. Peckham and S. A. Atkinson. C.P.* 508. 1960.
Gives preliminary results of low speed balance measurements and flow visualisation tests, on a wing of aspect ratio 1·0. The wing had a convex parabolic leading edge shape in plan view, and an unswept trailing edge. All edges were sharp, the centre section was 12 per cent biconvex, and transverse sections were diamond shaped. Where possible results are compared with tests on other wings of aspect ratio 1·0 with unswept trailing edges.—(1.10.2.2×1.8.1.2).

The properties of a thin conically cambered wing according to slender-body theory. J. H. B. Smith. R. & M. 3135. 1960.
Slender-body theory is used to calculate the lift and drag forces acting on a thin slender delta wing cambered to form part of the surface of a circular cone, in the type of flow in which separation is from the trailing edge only. The boundary condition satisfied by the flow on the wing surface is applied there, instead of on a nearby plane as is usual.—(1.10.12).

TESTING AND INSTRUMENTS *see also* COMPRESSIBLE FLOW

The representation of engine airflow in wind-tunnel model testing. J. Seddon and L. F. Nicholson. R. & M. 3079. 1960.
The problems of engine air flow representation in wind tunnel models are reviewed. Methods which have been used satisfactorily in low subsonic tunnels are described. Special difficulties associated with testing at transonic speeds are noted. Techniques of special application to small tunnels are described.—(1.12.1×27.1.2).

The measurement of unsteady forces and moments on slender bodies oscillating in a wind tunnel. J. F. Clarke. R. & M. 3170. 1960.
An apparatus for the measurement of unsteady aerodynamic reactions on slender bodies is described. It is particularly suited at supersonic speeds. The forces and moments on the model are detected by strain gauges attached to the mounting sting and by supplying their bridge circuits with properly phased a.c. of the right frequency, direct meter readings of the stiffness or damping reactions may be obtained. Results of tests on a cone-cylinder at subsonic Mach numbers and reduced frequency parameters up to 0·06 are given.—(1.12.6.2×1.6.3).

Progress report on development of telemetry for a hypervelocity range. M. K. Kingery et al. *A.E.D.C.-T.N.*-60-214. 1960.
This report concerns the development of a multi-channel telemetry system for measurement of heat transfer rates, pressure distributions, and accelerations experienced by free-flight models launched from a hypervelocity gun. Telemetering of pressure data from a gun-launched model in free flight after being subjected to accelerations from 100,000 to 550,000 *g* was investigated. An ultimate acceleration capability of one million *g* is being sought. Several types of circuitry were evaluated for telemetering pressure data.—(1.12.6).

Hypervelocity arc-tunnel instrumentation. W. T. Earheart and D. S. Bynum. A.E.D.C.-T.N.-60-227. *Dec.* 1960.
Some of the instrumentation developments necessary to instrument the arc discharge or hotshot type tunnels at the A.E.D.C. are presented. Force, pressure, and heat transfer measuring devices and systems, as well as the complete data readout system, are discussed. This includes a high speed analogue-to-digital system which is currently undergoing evaluation. In the force section a three-component balance, which has been used for tunnel contractor tests, is described. Also, a six-component balance system, currently under evaluation, including techniques of calibration and dynamic response on both balances, is presented.—(1.12.1.3×1.12.4×1.12.6.1).

Application des décharges électriques a l'exploration des écoulements gazeux aux grandes vitesses. P. Couvertier. Pubs Sc et Techs. 365. *(In French.)*
Attempts are made to extend the methods of high speed photography to the study of flow of gases at greater and greater speeds. To achieve this, for the electric arcs which were previously used the authors have substituted rarefied gas discharge tubes and then surface discharge spark gaps.—(1.12.6).

AEROELASTICITY

See also AERODYNAMICS—CONTROLS
INTERNAL FLOW

Some divergence characteristics of low-aspect-ratio wings at transonic and supersonic speeds. D. S. Woolston et al. *N.A.S.A. T.N. D-461. Sept.* 1960.
The problem of chordwise divergence is treated with primary emphasis on slender delta wings which have cantilever support at the trailing edge. Experimental and analytical results are presented for four wing models having apex angles of 5°, 10°, 15° and 20°. The analytical results include calculations based on low aspect ratio theory, lifting surface theory, and strip theory. A Mach number range from 0·8 to 7·3 is covered.—(2×1.10.2.2×1.6×33.1.1).

Wind-tunnel tests on the effect of a localised mass on the flutter of a swept-back wing with fixed root. D. R. Gaukroger. R. & M. 3141. 1960.
Wind tunnel tests to determine the flutter characteristics of a model wing, carrying a localised mass, are described. The investigation covers the effects of wing sweepback, and of the magnitude and position of the localised mass. Consideration is also given to the effects of pitching radius of gyration and aerodynamic shape. The mass values used vary from 0·13 to 1·17 times the wing mass.—(2).

Étude par analogie électrique des surface portantes en régime instationnaire. R. Duquenne. O.N.E.R.A. Pub. 98. 1960. (*French.*)
An analogue method of calculating unsteady incompressible linearised flow is described. Reports which have examined by means of the electric tank the theory of lifting surfaces in steady flow are summarised. The computer for unsteady lifting surfaces which resulted from these studies is described. After verification of the method by the results of the few theoretical cases which allow a rigorous solution, examples of application of practical interest are given. Theorems of reversed flow give an overall check for each particular case. Direct study of transitory conditions is approached in a simple case. The flexibility and speed of the method allows a preliminary generalisation of unsteady compressible flows.—(2×1.10.1 ×18.1).

AIRCRAFT OPERATION

See AERODYNAMICS—FLUID DYNAMICS
INTERNAL FLOW
STABILITY AND CONTROL

Correlation in the random pressure field close to a jet. R. E. Franklin and J. H. Foxwell. R. & M. 3161. 1960.
A suggestion that a relationship exists between the auto-correlation of the fluctuating pressure near to a jet and the space correlation along lines parallel to the boundary of the jet is examined and confirmed. The ideas involved are used to account for the fact that the longitudinal space correlation curve is independent of jet speed, and this is illustrated by a simple calculation and an experiment. The explanation is expanded to demonstrate the possibility of similarity between model and full-size experiments, and this possibility is confirmed by a comparison with similar full-scale work done at R.A.E.—(5.6).

A theory of the sound from jets and other flows in terms of simple sources. H. S. Ribner. U.T.I.A. Report 67. *July* 1960.
The elementary generators of flow noise are pictured as source-like pulsations of the moving fluid elements in response to the local inertially-produced pressure fluctuations. The sources, although individually non-directional, jointly yield a directionality for the radiated sound from jets. Use of the two-point covariance of source strength with retarded time provides a formalism for treating the convective effects. The formalism is applied to simulated jets to calculate convective spectrum effects in the source field, Doppler shifts in the far field, and overall directionality of the radiated sound for both static and subsonically moving jets.—(5.6×32.2.3).

EXTRA-ATMOSPHERIC TECHNOLOGY

An attempt to determine certain parameters of the earth's gravitational field from the results of observations of satellites 1957 $\beta 2$, 1958 $\delta 1$, 1958 $\delta 2$. *I. D. Zhongolovich. R.A.E. Lib. Trans.* 913. 1960.

Explains how the coefficients J, c_{30} and D of the second, third and fourth harmonics in the earth's gravitational potential can be derived from the perturbations of the node and perigee of a single earth satellite. The fundamental formulae are given and the method is applied to the sets of orbital elements obtained at R.A.E. of Sputnik 2, Sputnik 3 and its rocket.—(8.2).

A method for the correction of orbits of artificial earth satellites when the observation times are known only approximately. D. K. Kulikov and Yu. V. Batrakov. R.A.E. Lib. Trans. 918. *Oct.* 1960.
A method is given for improving the orbital elements of artificial satellites, the time of observation being only approximately known. Corresponding equations of condition have been received, one of which is independent of time errors. It is shown that some elements can be determined from the equations which are independent of time errors. An analysis of the optimum conditions for determining these elements has been made. Equations of conditions are given for corrections of the absolute co-ordinates of observational stations with an analysis of these equations. A numerical example illustrates the method for improving the elements.—(8.2).

Report on optical observations on the occasion of the landing of the Soviet moon probe Lunik II. L. Detre. R.A.E. Lib. Trans. 922. *Nov.* 1960.
On 13th September 1959, in Hungary an expanding dark spot on the moon, near the crater Autolycus, was observed by several astronomers at two independent observatories, between the times 21h 02m 30s and 21h 07m UT. Traces of a similar phenomenon were found on photographs taken at the same time at Uppsala. The co-ordinates of the dark spot (+0·03 +0·45) agree well with those given for the impact point of Lunik II, which hit the moon at 21h 02m 24s UT.—(8.2).

Interim definitive orbit for the satellite 1959 *Alpha Vanguard-II. Goddard Space Flight Center. N.A.S.A. T.N. D*-411. 1960.
A summary of certain position information indicating accuracies for the orbital arcs underlying the ephemeris is presented. The detailed ephemeris information is presented in the form of tables which give the latitude and longitude of the subsatellite point and the satellite height for each minute of time. The subsatellite point is the point on the earth's surface over which the satellite was determined to be at the indicated time.—(8.2).

An exploratory statistical analysis of a planet approach-phase guidance scheme using angular measurements with significant error. A. L. Friedlander and D. P. Harry. N.A.S.A. T.N. D-471. *Sept.* 1960.
An analytical and statistical analysis of vehicle guidance during the approach to a planet is presented. The target of guidance is defined in terms of a perigee distance. A simplified navigation scheme is hypothesised using appropriate instrumentation to determine range to the planet and a reference angle in the trajectory plane. Guidance initiation and the number of corrections are varied parametrically to determine optimum values. Non-dimensional results, applicable to any planet, are evaluated primarily on the basis of final guidance accuracy and corrective velocity-increment requirements.—(8.2×26×25.1).

INSTRUMENTS AND EQUIPMENT

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MATHEMATICS

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MISSILES

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